LAN-Based Measurement Systems

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Abstract-Computer network–based solutions represent an important trend in the evolution of measurement systems. The network-based measurement systems use principally LANs and the Internet. Three types of LAN based measurement systems are described in the paper. We investigated a simple measurement system equipped with both GPIB and LAN interface. We measured command execution times in both systems. We compared some technical parameters of the GPIB interface system and LAN interface system.

I. Ethernet-Based Measurement Systems with LAN/IEEE-488 Converters

LANs provide an infrastructure that can be used in computer measurement systems. LAN-based measurement systems can be grouped into three types: hierarchical systems, systems with LAN interface, and systems with GPIB/LAN converters [1]. We compared some parameters of the LAN-based measurement systems to systems with the IEEE-488 interface (generic name of the IEEE-488 is GPIB). Hierarchical measurement systems are composed of subsystems, subsystem controllers, and a system controller. Subsystems, forming the bottom level of a hierarchical system, use interfaces such as GPIB or RS-232. Each subsystem is individually controlled by a PC. The top level of a hierarchical measurement system is organized by means of a LAN, connecting the subsystem controllers and the system controller, which can be a PC or a workstation. Used in hierarchical measurement systems, LAN provides standard communication between computers, based on data and message exchange. GPIB interface systems with GPIB/LAN converters, representing the second group of LAN-based measurement systems, are composed of the following parts: the system controller with LAN interface card; the instruments attached to a GPIB interface primary bus; one or more GPIB interface secondary bus segments; the LAN; the GPIB/LAN converters, through which GPIB bus segments are connected to the LAN, as shown in Figure 1.
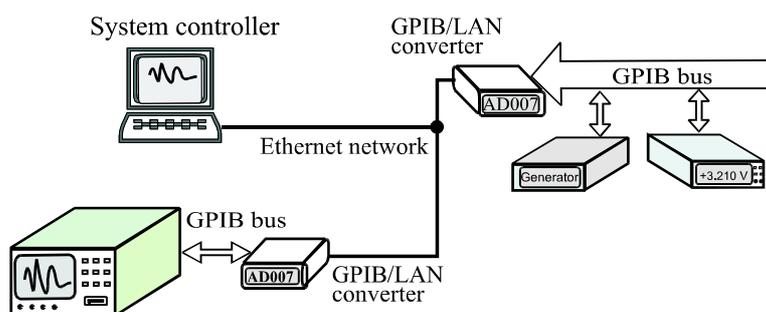

Figure 1 LAN-based measurement system with a GPIB interface and GPIB/LAN converters

A computer connected to the network should have an implementation of the TCP/IP network protocol suite. A computer with TCP/IP can be used as a controller of a distributed measurement system with GPIB/LAN converters. LAN allows transmission of control signals from the controller to the instruments, and transmission of measurement data from the instruments to the controller. The system uses e.g., AD007 LAN/GPIB converters, manufactured by Tektronix and designed for operation with 10BaseT Ethernet. In 100BaseTX and 10BaseT Ethernet [2] variations, a LAN/GPIB converter can be used, which allows data transfer to and from the GPIB interface at rates up to 900 KBps by IEEE-488.1 transfer protocol, and up to 1.2 MBps in transfers using HS488 protocol. The throughput limitations in the measurement system are due to the presence of GPIB.

In measurement systems with a LAN interface, the third group, both the controller (PC) and the instruments are attached directly to the LAN, with no interface converter. This type of system is discussed next.

II. Measurement Systems with a LAN Interface

In measurement systems with a LAN interface, both the controller and the instruments are equipped with LAN interface cards, allowing direct connection to the network, without interface converters. In this type of system, the LAN is used as a bus interface. Measurement systems with a LAN interface (or more specifically, Ethernet interface) represent a new solution, since instruments equipped with LAN interface cards have been manufactured for only a few years. Each instrument with a LAN interface card is supplied with suitable software, allowing the instrument to act as a Web server. This is a very important feature of instruments with a LAN interface. Using a Web browser, which is included in almost every PC, a remote computer (client) can access a Web server instrument to get measurement data or operate the instrument. Installation of a measurement system with a LAN interface and Web server instruments does not involve purchasing specialized system software, and thus allows substantial savings. Although currently only higher class instruments are supplied with a LAN interface, the range of available instruments is rapidly growing. A schematic of a measurement system with a LAN (Ethernet) interface is shown in Figure 2.
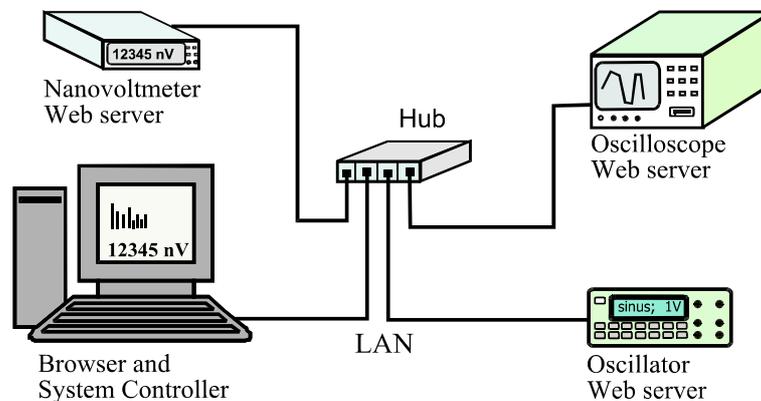

Figure 2. Measurement system with a LAN interface

The list of LAN interface implementations in instruments includes, but is certainly not limited to, products and product lines of the following companies: *Tektronix*, which implemented the 10/100BaseT Ethernet interface as standard fitting in the TDS6000 series digital oscilloscopes, as well as in the TG700 signal generator; *LeCroy*, the manufacturer of digital oscilloscopes, which equipped the WaveRunner 6000 series with a 10/100BaseT Ethernet interface; *Agilent Technologies,* which implemented the 10/100BaseT Ethernet interface in its Infiniium oscilloscope series and the 33220A function/arbitrary wave form generators; *Keithley*, the instrument manufacturer offering digital multimeters, including the Model 2701 Multimeter/Data Acquisition System with 10/100BaseT Ethernet interface. These devices all have RJ-45 sockets, compatible with the 10/100BaseT Ethernet standards. The list includes only arbitrarily selected products of arbitrarily selected manufacturers. Although certainly not exhaustive, it illustrates the growth of measurement systems with a LAN interface as an important trend in measurement system evolution. Each device with a LAN interface can be used as a Web server, allowing access to measurement data and remote operation from a Web browser.

III. Measurements of command execution time in LAN-based measurement systems and in GPIB measurement systems

We measured the total time of a command execution in a measurement system equipped with two interfaces: the GPIB as well as the LAN interface. The measurement system consisted of the arbitrary waveform generator of the Agilent 33220A type (equipped with both GPIB and LAN interface [3]) and the PC computer with the Pentium 4 processor (clock 2.4 GHz) − see Fig. 3. The computer is operated by Windows XP Professional. For minimize the influence of the operating system itself on measurements one switched off the screen saver, the energy saving system and deinstalled the antivirus program. For the system working in the GPIB mode one switched off the network service. The Agilent

33220A generator is a device programmed according to the SCPI standard. The measurement of the command execution in the system is made by the measurement of time signals at the RS-232C connector (RTS line) on PC. The delay caused by the interface RS-232C itself in PC amounts only 62 μs and can be neglected for measured times longer than 50 ms,.
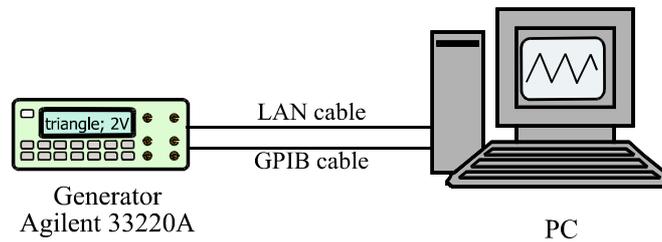

Figure 3. Setup for measurements of command execution total time in measurement system with LAN interface and GPIB interface

The commands to be measured in our experiment are a data download (data with a waveform defined by user) from PC to the generator. The download operation includes a data transmission (between PC and a generator) and a data acquisition, including data writing into a volatile memory of the generator. Thus the total download time t_C is the sum of the transmission time t_T and the acquisition time.
The software used in the measurement system is MS Visual C++ 6.0. Running of the GPIB or the LAN interface is possible with one from three types of recommended drivers: VXIplug&play, IVI-COM or VISA. We used the VXIplug&play driver provided by Agilent. The waveform data can be sent to the generator in one of two formats:
− binary block format,
− decimal integer format.
The VXIplug&play driver enables to use only the decimal integer format for data sending. In Figure 4 results of measurement of the total download time t_C are plotted as the function of a data length d (in kilobytes, KB) in the GPIB interface system. Different short lines in Fig. 4 show the measurement results for different points numbers n of arbitrary defined waveform (from 4096 to 32768 points per waveform) transmitted to the generator. Each measurement point displayed in Fig. 4 is the mean value from 500 separate measurements. The long line in Fig. 4 presents the relevant total download times published by Agilent in the 33220A generator catalogue [3].
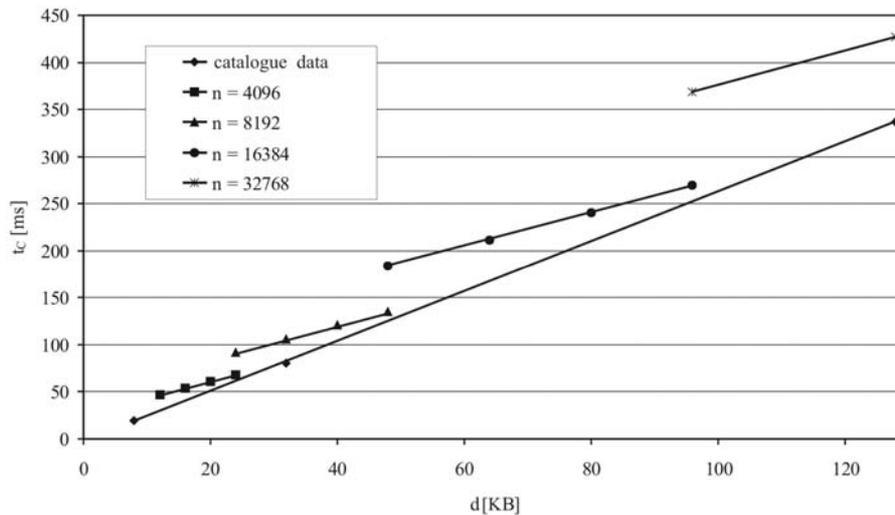

Figure 4. Download times t_C versus data length d for the GPIB interface system: four short lines − measured times and one long line − catalogue times

Similar measurements were carried out for the LAN interface system. The measurements results are shown in Fig. 5. In both figures (Fig. 4 and Fig. 5) catalogue download times are shorter than download times t_c measured in our experiment.
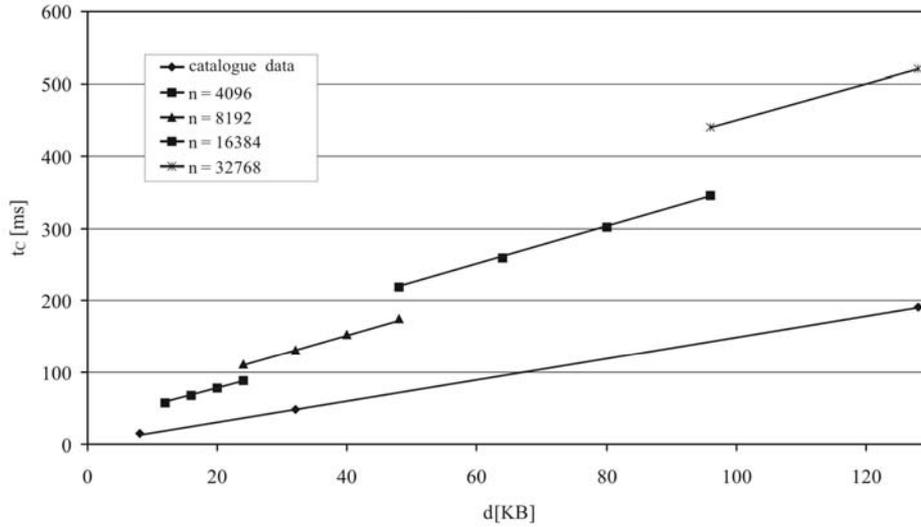
Figure 5. Download times t_C versus data length d for the LAN interface system: four short lines −
measured times and one long line − catalogue times

This difference between catalogue times and measured times results from the data format: data in the decimal integer format require longer download time that data organized in the binary block format. In our measurements the sent data were prepared in the decimal integer format. The catalogue download times are given from measurements with data in the binary block format. In Table 1 results of measurement of download times t_C for the GPIB system and $n = 8192$ are presented. A data length depends on data format and it varied from $d = 24$ KB for the format "+1," to $d = 48$ KB for the format "+1234,". The download times increased from 92 ms (for $d = 24$ KB) to 135 ms (for $d = 48$ KB) with a step of 14 ms for a step $\Delta d = 8$ KB. We assumed that the acquisition time does not depend on a data length d. The acquisition time was about 50 ms. Thus the increasing in the download time results from longer transmission operation. For the GPIB interface system measurements of download times t_C and calculations of transmission times t_T were done for $n = 4096, 16384,$ and 32768 as well.

Table 1. Download time t_C and transmission time t_T in the GPIB interface system (number of waveform points $n = 8192$)

i	n	Data format	d [KB]	t_C [ms]	t_T [ms]
1	8192	+1, ...	24	92,11±0,02	42
2	8192	+12, ...	32	106,23±0,02	56
3	8192	+123, ...	40	121,02±0,03	71
4	8192	+1234, ...	48	135,38±0,03	85

where: n − the number of waveform points, d – the length of data to be send to the generator, t_C − the data download time from PC to the generator, t_T − the transmission time.

Similar measurements of download times t_C were carried out for the LAN interface system for same number of waveform points: $n = 4096, 8192, 16384,$ and 32768. In Figure 6 transmission times t_T versus data length d for GPIB interface and LAN interface are shown. Each point in Fig. 6 is obtained from 500 measurement operations. We can note that transmission times are shorter in the GPIB interface system than in the LAN interface system.

IV. Conclusions

The IEEE-488 (GPIB) has been the dominant interface standard in measurement systems for 20 years. However, numerous technical and cost advantages of LAN, introduced into the measurement systems, make it an important option to be considered by measurement system developers [1]. Some aspects of LAN (the Ethernet version) and GPIB are compared next:
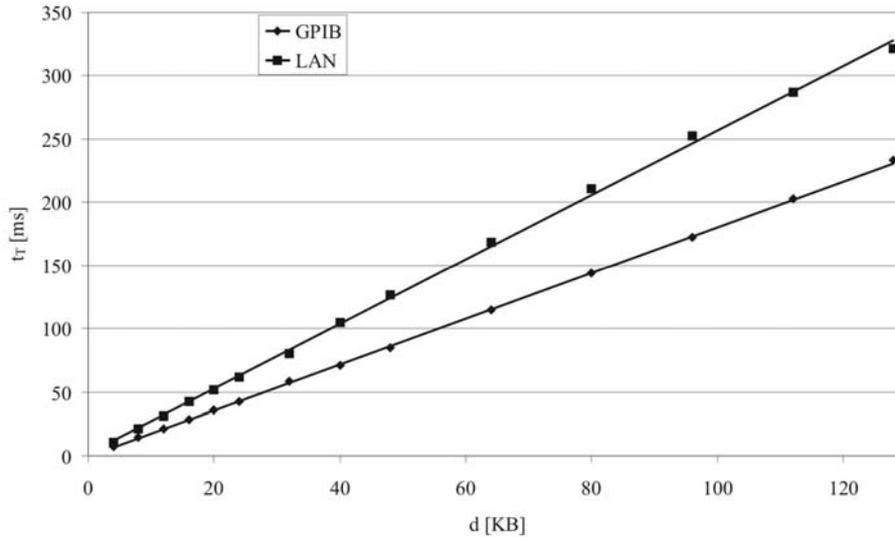
Figure 6. Transmission time t_T in the function of data lengths d for GPIB and LAN-based measurement system

1. Maximum transfer rate in the GPIB interface is 1 MBps, with possible enhancement to 8 MBps in transfers using the HS488 protocol. Ethernet allows throughput from 10 Mbps (about 1.2 MBps) in 10BaseT to 1,000 Mbps in 1000BaseT. Therefore, transfer rates offered by Ethernet are much higher than those achievable in GPIB.
2. Command execution times are longer (up to 50%) in the LAN interface system than in the GPIB interface, as shown in Section III.
3. Format of data transmitted in an interface system is important for reducing of command execution time. The binary block format is better than the decimal integer format.
4. Maximum cable length between two instruments in the GPIB interface is 2m, against 200m (device-hub-device distance) allowed by Ethernet.
5. The price of a 2m GPIB cable is $100, against approximately $10 for 200m of Ethernet cable.
6. A plug-in GPIB interface card for a PC costs about $500. Ethernet interface cards are installed in PCs as standard fitting; if an Ethernet interface card is to be purchased, it costs as little as $10.

Although IEEE-488 (GPIB) is still the dominant interface standard in the field of measurement systems, its predominance in the next five years is seriously threatened by the LAN interface.

References

[1] IEEE-802.3 Standards, *Computer Local and Metropolitan Networks,* 1992–2004.
[2] Nawrocki W., *Measurement Systems and Sensors*, Artech House, Boston, 2005.
[3] Users Manual, 33220A Arbitrary Waveform Generator, Agilent Technologies.