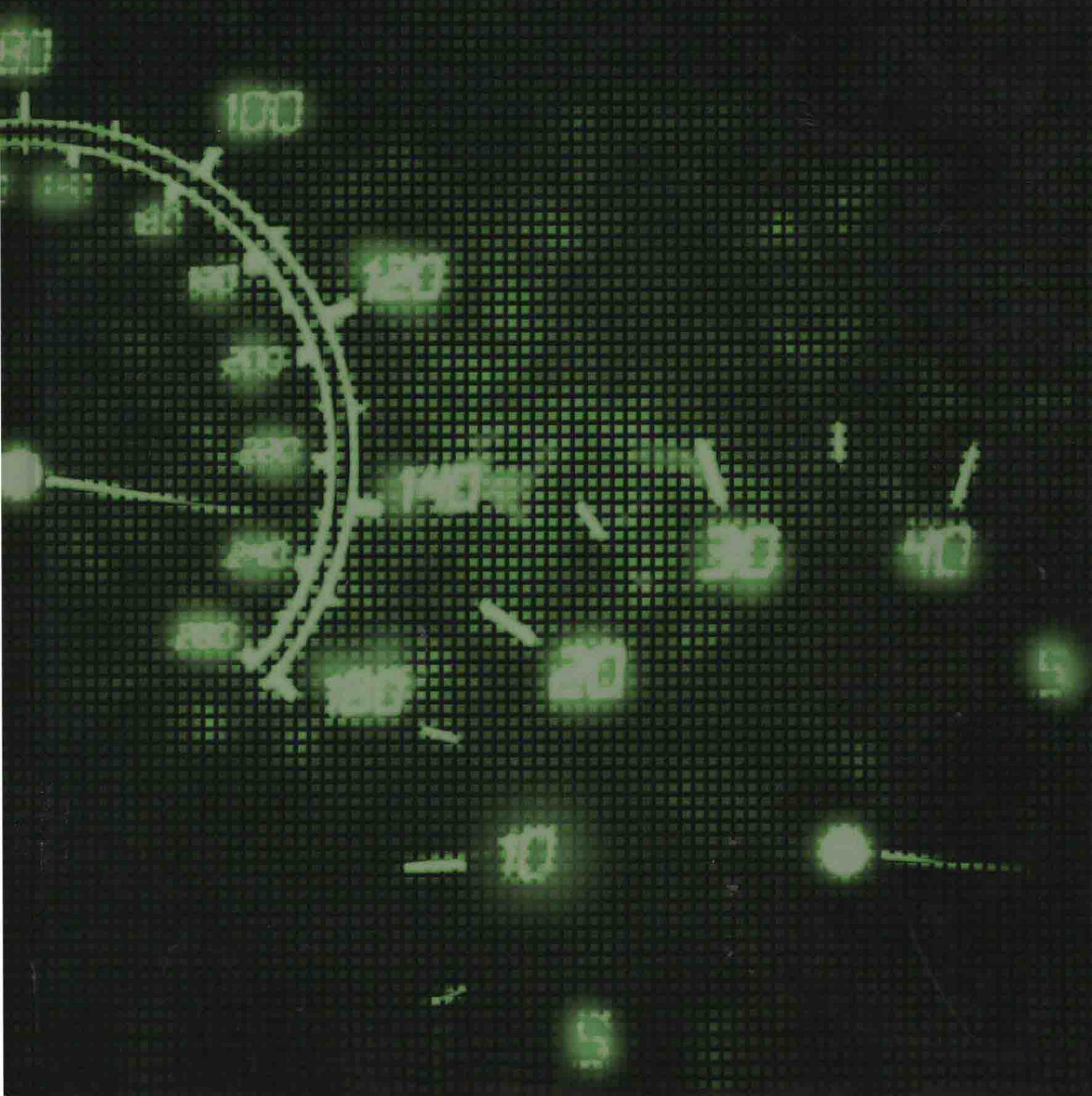
Wa[illegible]ki

MEASUREMENT SYSTEMS AND SENSORS

SECOND EDITION



Measurement Systems and Sensors

Second Edition

Waldemar Nawrocki

ARTECH
HOUSE

BOSTON | LONDON
artechhouse.com

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the U.S. Library of Congress.

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library.

Cover design by John Gomes

ISBN 13: 978-1-60807-932-2

685 Canton Street
Norwood, MA 02062

10 9 8 7 6 5 4 3 2 1

Measurement Systems and Sensors

Second Edition

For a complete listing of titles in the
Artech House Remote Sensing Library,
turn to the back of this book.

Contents

Chapter 1

Computer-Based Measurement Systems

One of the components of measurement technology development is the development of measurement systems. By the measurement systems, we refer to a set of material and organizational resources, as well as software for information processing, aggregated in order to obtain, transmit, and process measuring data, and to display and store them. The measurement system is equipped with a personal computer (PC) or a microprocessor chip; its task is to control information flow in the system, to process measuring data, and sometimes to store them. The computer or the microprocessor chip is a system controller; that is a device managing the system. The measurement systems described in this book are exclusively digital systems. Measurement systems with the PC, called computer-based measurement systems, are of great importance. Considering the widespread use of PCs in both industrial and research measuring laboratories, the building of a computer measurement system usually does not imply the purchase of a separate computer, but allows the utilization of the existing ones. This is especially important and economically effective in the case of building up computer measurement systems for the realization of temporary measuring tasks. Separate classes of computer measurement systems are the simplest two-component systems, composed of one measuring instrument plus one computer as the system controller. It is self-evident that the possibility of applying an existing computer for setting up the simplest measurement system decreases construction expenses of such a system considerably.

1.1 CONFIGURATION AND STRUCTURE OF MEASUREMENT SYSTEMS

An important problem in designing and operating the measurement system is the organization of information flow in the system. Two criteria are essential for this organization:

- The kind of transmission in the system: serial, bit-by-bit, or parallel, where the information is transmitted in the form of multibit words. According to this criterion, there are systems with serial interfaces and parallel interfaces.
- The mode of information exchange between system devices with regard to the connection configuration of instruments: linear (bus), star, or daisy chain (arranged in rows).

Measurement systems in the linear, star, or daisy chain configurations are shown in Figure 1.1. The linear configuration is used most often; in this configuration, the exchange of instructions passed between system devices is realized exclusively by the data bus of the system. The linear configuration is elastic because it makes change of the system structure readily possible by adding or disconnecting devices or by changing the placement of instruments in relation to other devices.

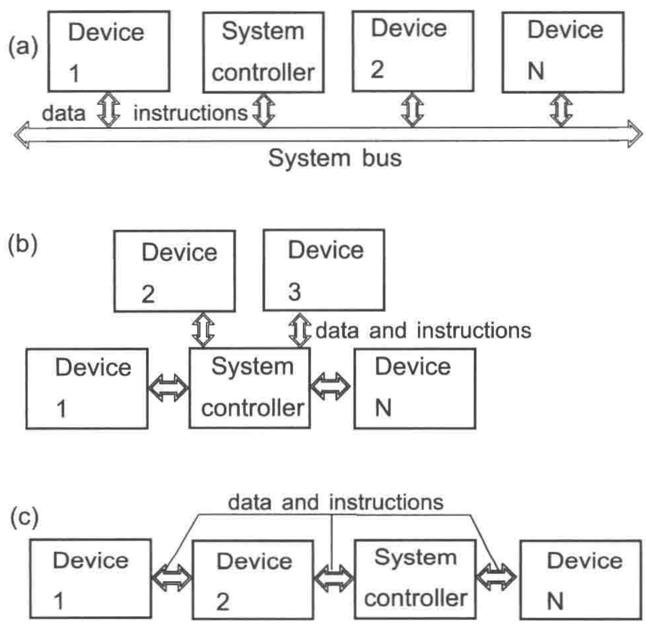


Figure 1.1 Configuration of measurement system: (a) linear, (b) star, and (c) daisy chain.

The star configuration requires the number of multibit computer inputs equal to the number of devices in the system (except for the computer). An advantage of this configuration is the fact that it does not address the bus devices because they are connected to determined computer inputs. Alteration of the structure of such a system is difficult, and sometimes impossible, since the measurement system contains a greater number of instruments. Even less elastic is the daisy chain configuration, in which the exchange is possible only between neighboring instruments. Such configuration is sometimes used in the case of simple measurement systems

with the only one way of information flow. In discussing measurement system configurations, it must be remembered that a lot of measurement systems consist of two components only: the controller and the measurement instrument. The problem of system configuration thus does not appear.
The measurement system designed for measuring various physical quantities in the object consists of the following functional components:

- A sensor or a set of sensors of physical quantities. The sensor causes changes of a definite electric parameter in the function of the value of a measured quantity (e.g., the resistance alteration in the function of temperature).
- Measurement transducers, in which the electric parameter of the sensor is transformed into the direct voltage or the direct current (e.g., a transducer as the Wheatstone bridge with the bridge branch as resistance sensor with the electric voltage at the bridge output).
- Conditioners or circuits standardizing the level of signal from the measurement transducer to the range of the input voltage of the analog-to-digital converter (ADC).
- ADCs or digital measuring instruments containing such a converter; the task of ADCs is to convert analog into digital signals.
- Devices for visual display of measurement results in the form of the display field of a digital measurement instrument, the screen of a digital instrument (e.g., the digital oscilloscope or the frequency analyzer), or a computer monitor.
- A computer with its software and memory resources.
- Actuators or generators of test signals.
- Power supplies of the object, operating autonomously or under control (optional).

The flow-process diagram in a measurement system is shown in Figure 1.2. It is worth mentioning that the measurement system is often—particularly in industry—part of a control-measurement system. Measuring data is for controlling objects measured, for diagnosing the objects, and monitoring their state.
More complicated measurement systems can be constructed in the hierarchical structure. On the lowest level, there are measurement subsystems arranged to collect data from the object. Subsystems are situated on a separate area (e.g., in the manufacturing room or the laboratory). Data from such subsystems are sent to the main controller of the measurement system (see Figure 1.3). The main controller of the system not only receives initially processed measuring data, but it can also send commands relating to the execution of a measuring procedure or a set of commands for measurement instruments to subsystems. The main controller of the measurement system can also take advantage of memory resources, data display, and data storage devices.

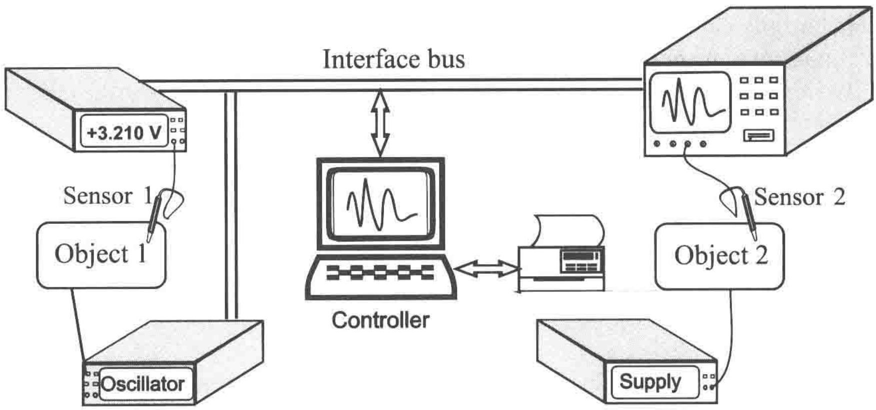


Figure 1.2 The flow-process diagram in a measurement system.

These devices would not be effectively used in subsystems. The PC, Mac, laptop, tablet or similar class computer—as the main controller of the measurement system—can be programmed for a synthesis of collected measuring data and for advanced processing, as well as for data presentation. Interface systems on different levels of the hierarchical measurement system can belong to different interface standards.

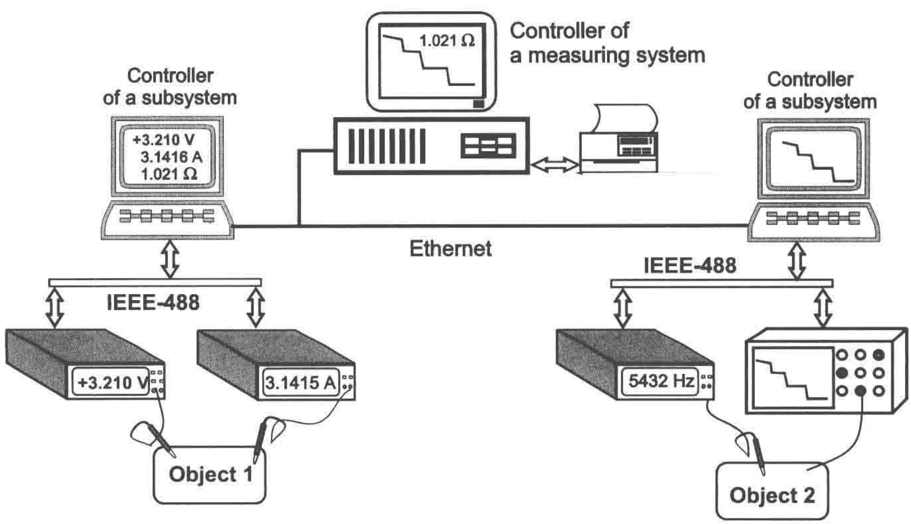


Figure 1.3 The hierarchical structure of the measurement system.

In the example shown in Figure 1.3, each subsystem is composed in the standard of the IEEE-488 parallel interface. All subsystems are united into the system by means of the local area network (LAN) computer network, the Ethernet type with serial transmission. For the implementation of such a configuration, the computer in a subsystem must be equipped with the IEEE-488 interface board and the Ethernet network board. Some interface standards (e.g., Profibus or VXI) make it possible to build up hierarchical systems in the frame of one interface system.

1.2 INTERFACE SYSTEM

A generally applied criterion of the division of measurement systems is a kind of transmission of digital announcements in the system (e.g., data, addresses, and commands); in other words, serial transmission or parallel transmission. The interface system assures equipment and programmatic adjustment of devices attached to the bus. According to the criterion mentioned, measurement systems are divided into the following categories:

- Measurement systems with serial interface;
- Measurement systems with parallel interface.

The interface systems used most often in computer-based measurement systems are the following: the RS-232 serial interface and the IEEE-488 parallel interface (also called IEC-625, HPIB, or GPIB).

1.2.1 Interface System Meaning

There is a notion of an interface system, as well as a notion of an interface only, which have a wider and a narrower sense, respectively. They are defined in standards. According to the standard, "interface is the coupling between a system considered and another system, or between devices of a system, through which information passes." Interface in the narrower sense is only a matching-up circuit (e.g., matching-up signals of the TTL circuits to signals of the CMOS circuits), or adapting binary signals coded with voltage levels (e.g., logical 0 is 0V; logical 1 is 4.5V) for of binary signals coded with impulse frequency (e.g., logical 0 means 2,200 Hz; logical 1 means 1,200 Hz). The wider sense is given to the interface system, which according to the standard means, "the gathering of device-independent components—mechanical, electrical, and functional—necessary in the process of information exchange between devices." Such gathering requires "cables, junctions, signal transmitters and signal receivers, interface functions with their logical description, the line signal, time relations as well as control rules." Transmission protocols and control programs concerning system operation also belong to the interface system. In the common parlance, the notion of interface is often relevantly used instead of the notion of interface system. In this book, we will also take advantage of this abbreviation. It should be once again emphasized that the interface system describes (defines) the processing of only those signals that are transferred through an interface bus. Other signals in the measurement system, including very essential input measuring signals, both analog and digital, are neither defined nor standardized by the interface standard.

1.2.2 Interface Bus

Signals transmitted through an interface bus bear the general name of interface messages. Interface messages are divided into data and instructions. The data transmitted is not only the result of measurement (measuring data), but also sets of instruments: measurement ranges, limit values for alarms, sets of power supply, sets of oscillators, the mode and the level of triggering oscilloscopes, and others. Instructions in the interface system are divided into commands and addresses.

Certainly, the organization of the interface bus depends on the kind of interface. Parallel interface buses are more complex. The lines of the parallel interface bus are divided into groups that are also called buses. A separate bus of the parallel interface is always the *data bus*. The data bus contains 4 lines (Centronics) to 64 lines (PXI). The *synchronization bus* contains lines assuring time coordination between the sending and the accepting of data. The *control bus* (or *interface management bus*) contains lines destined for transmission of control signals. Control signals in a measurement system are the signal of resetting, interrupt request signals, commands of measurement execution, commands of generating a set of signals (for a generator in the system), and others. The *address bus* destiny is defined by its name. Binary addresses are transmitted across this bus. The addresses are sent to these devices, which ought to execute commands; related commands are available on the control bus. Quicker addressing takes place when the number of lines in the address bus is equal to the number of instruments included in the system. In such a case, addressing is performed with the "1 from n" method. In cassette (crate) systems with the parallel interface, a bus for clock pulses is set up. Sometimes, one part of the bus is the local rail, the line of which connects only neighboring modules in the cassette, and thus, as opposed to other lines in the interface bus, they are not led to all devices in the system. For particular systems of the parallel interface, the organization of the interface bus may differ considerably from the organization described above. For example, in the CAMAC system there are two separate data buses, each with 24 lines. One CAMAC data bus is provided for recorded data, the other for readout data. However, in the IEEE-488 system, the data bus serves not only for data transmission, but for addresses transmission as well.

The bus of the serial interface can number two or more lines. The messages transmitted are organized according to careful rules and standards called communication protocols. The interface message frame contains both the receiver address and the data field; it also contains the field of control bits as well as redundant CRC bits for transmission validity check. The CAN and MicroLAN measuring-control systems have a similar data bus. In spite of a trivial opinion evaluating the number of lines of each serial interface to two, this bus can have anything from 2 to 35 lines, as in the RS-449 interface. They are mostly control