Computer-Based Instrumentation: A Boost for Industrialization.

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ABSTRACT

This paper discusses the various methods by which instruments used in industries and process control can be computer-based. Instruments can be connected to computers so that collecting, controlling, and adjusting parameters under the supervision of computer program is facilitated. This paper discusses various methods of data acquisition by which properties exhibited by various instruments can be acquired in an appropriate form, processed, and made ready for the computer environment.

This paper also examines the means of transmitting acquired signals to the appropriate interface system, which eventually links the computer system for processing and control. It thereafter concludes by advising the instrument and process control engineers to understand the main principles of communication to ensure proper integration into process control system and industrial environment.

(Keywords: instrumentation, PC, sensors, industrialization, non-compatible signal, digital computer, compatible)

INTRODUCTION

Industrialization is the process of social and economic change whereby a human group is transformed from a pre-industrial society (an economy where the amount of capital is low) to an industrial one (a fully developed economy). It is a part of wider the modernization process where social and economic change is clearly related with technological innovation, particularly the development of a large scale energy and metallurgy production.

Hence, the lack of a well-developed industrial sector is widely seen as a major handicap in a country's economy. For proper industrialization, a nation needs to developed its instrumentation technology as part of the industrialization process.

Instrumentation in technology, is the development and use of precise measuring equipment. While the sensory organs of the human body can be extremely sensitive and responsive, modern science and technology rely on the development of much more precise measuring and analytical tools for studying, monitoring, or controlling all kinds of phenomena. The development of instrumentation involves both measurement and control functions (Encyclopedia Britannica 2004). Most manufacturing processes rely on instrumentation for monitoring chemical, physical, and environmental properties, as well as the performance of production lines.

The rapid adoption of the personal computer (PC) in the last 20 years has catalyzed a revolution in instrumentation for test, measurement, and automation. One major development resulting from the ability of the PC is the concept of Computer-Based Instrumentation, which offers several benefits to agriculturalists, engineers, and scientists who desire productivity, accuracy, and performance.

A Computer-Based Instrumentation consists of an industrial-standard computer or workstation equipped with powerful application software, cost-effective hardware such as Plug-in board, and driver software, which together performs the functions of the instruments. It represents a fundamental shift from traditional hardware-centered instrument system to software centered ones that exploit the computing power, productivity, display, and connectivity capabilities of the popular desktop computers and workstations with which engineers and scientists build automation systems that suit their needs. Implementation can also enhance lower capital costs, system development costs, and system maintenance costs, while improving time to market and improving the quality of products.

Real-time applications require an interface to connect the instrument to the computer. The basic principle of interface designing is similar for most real-time micro or mini computer applications. Signals originating in the real-time device must be conditioned to match the input requirement of the computer. Similarly, computer signals must be converted to a form that can activate the required real-time output devices (Figure1).

Computer requirements include the need for digital input signals, which can generate digital output signal. Very few real-time devices of interest generate digital signals; some do not even generate electrical signals. It is therefore necessary to convert non-compatible signals of interest to digital computer compatible forms. In general, a special interface, including hardware and software must be designed and constructed for each new real-time application.

DISTRIBUTED APPLICATIONS

A virtual instrument is not limited or confined to a stand-alone PC. With recent developments in networking technologies and the Internet, it is more common for instruments to use the power of connectivity for the purpose of task sharing. Typical examples include supercomputers, distributed monitoring and control devices, as well as data or results visualization from multiple locations.

GENERAL OVERVIEW

Figure 1 shows how information from the device is passed to the computer. It separates the process into three parts: sensors, signal conditioning, and data acquisition. The choices made in the design of these systems ultimately determines how intuitive, appropriate, and reliable the interaction is between devices and computer.

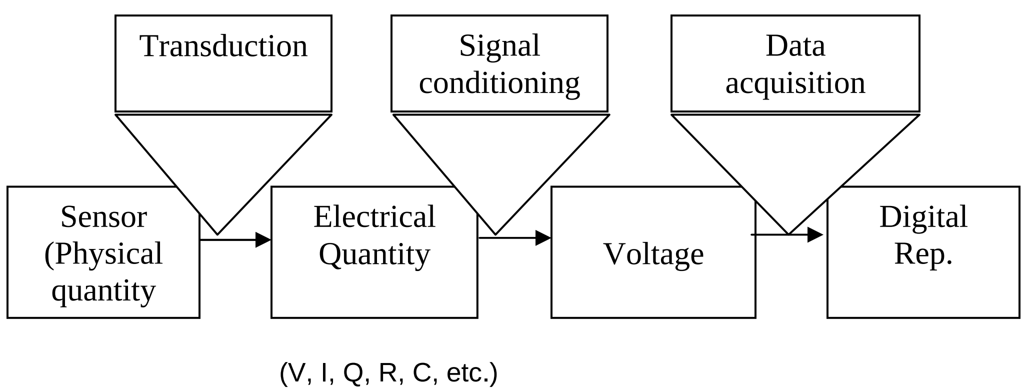

Figure 1: The Path from Human to Computer.

DATA ACQUISITION TECHNIQUES

Data acquisition and control systems need to acquire real-world signals into the computer. These signals come from a diverse range of instruments and sensors, and each type of signal needs special consideration (http//www.microlink.co.uk/dataak.htm). Some of these real-time signals are stated below:

- Voltage signals (voltage, conditioned transducer, level, and flow measurement)
- High impedance probes (concentration measurement)
- Current signals (current and conditioned transducer measurement)
- Power signals (power supply, current, and voltage measurement)
- Thermocouples (temperature measurement)
- Resistance (temperature, displacement, and light level measurement)
- Strain gauge bridges (strain measurement)
- Excitation (force, pressure, relative humidity, temperature level, light level, concentration; and vibration measurement)
- LVDTs (displacement measurement)
- Encoders (angular position measurement)
- Counter-Timers (speed and flow measurement)
- Digital signals (on/off measurement)

Sensors

Sensors can be categorized in many ways. They can be categorized by the underlying physics of their operation (Fibkel, 1932). However, one physical principle can be used to measure many different phenomena. For example piezoelectric effects measure force, flexure, acceleration, heat, and acoustic vibrations. Sensors can be categorized by the particular phenomena they measure. However, one phenomenon can be measured by many physical principles. For example, sound waves can be measured by piezoelectric effect, capacitance, electromagnetic field effect, and changes in resistance.

Signal Conditioning

After a sensor measures the target information, it must be changed to a form appropriate for input into the data acquisition system. In most applications, this means changing the sensors output to a voltage (if it isn't already), modifying the sensors dynamic range to maximize the accuracy of the data acquisition system, and removing unwanted signals. Additionally, analog signals processing (both linear and nonlinear) may be desired to alleviate processing load from the data acquisition system and computer.

Correct design of the signal conditioning system is critical in mapping the sensor output to data acquisition input. Incorrect choices can affect the way the computer reacts to the input. Thus, it is important to note the changes in the properties of the sensor signal caused by the conditioning circuitry.

Signal Conditioning Circuitry

The primary purpose for the analog signal conditioning circuitry is to modify the sensor output into a form that can be optimally compacted to a discrete time digital steam by the data acquisition system (Loxton and Pope). Some important input requirements of data acquisition system are:

1. The input must be a voltage waveform. The process of converting the sensor output to a voltage can also be used to reduce unwanted signals (i.e., noise).

2. The dynamic range of the input signal should be at or near the dynamic range of the data acquisition system (usually equal to the voltage reference level, Vref, or 2* Vref). This is important in maximizing the resolution of the analog to digital converter (ADC).

3. The source impedance, R_s, of the input signal should be low enough so that changes in the input impedance, Rn, of the data acquisition system do not affect the input signal.

Removal of undesired signals

Many sensor output signals may have many different components (noise) added to them. It may be desirable or even necessary to remove such components before the signal is digitalized for this may corrupt the sensor output. This "noise" can be removed using analog circuitry.

For example, 60Hz interference can distort the output of low output sensor (Ott, 1998). The signal conditioning circuitry can remove this before it is amplified and digitized.

SIGNAL TRANSMISSION AND COMMUNICATION TECHNIQUE

For the human race, communication is a fundamental requirement of life and social interaction. Without the ability to pass information, it is unlikely that our species could have survived. This same basis applies in modern industries. There must be an ability to transmit information around a process control system, be it a simple measurement or a plant automatic system. The development of control systems from simple mechanical indicators and distributed micro processor based systems has required equal development in the methods of transmitting and communication between devices (Mathew, 1982).

There are basically three transmission carriers:

(i) Pneumatics
(ii) Light
(iii) Electrical

Pneumatic Transmission is the use of a comprehensive fluid to transmit analog signals. Light transmission involves the use of optical and photoelectric devices. The signals from the optical detectors (analog or digital) can then be further processed. This paper concentrated the more on the use of electrical methods of signal transmission.

Industrial process control is increasingly dominated by electronic instrumentation. The use of electrical methods for transmission is therefore the obvious method of communication between instruments. There are basically two types of electrical method of transmission:

(i) Analog
(ii) Digital

An environment created to incorporate various forms of electrical methods of signal transmission between instruments and computer is called an interface.

COMPUTER INTERFACE FOR INSTRUMENTATION SYSTEMS

The interfaces commonly used to connect computers to instrumentation systems are briefly discussed below. This is not intended to be definitive, or very detailed, listing, but it serves to give an idea of what has readily been achieved with the various systems.

RS-232

The interface now described by the Electronic Industries Association and the RS-232-C standard was started in the late 1960s as a method for connecting a computer to a modem. A full implementation comprises 2 data lines, 6 control lines, and one ground. Data is transmitted using a serial (i.e., one bit at a time) full-duplex (i.e., simultaneous send and receive is possible) at a rate governed by the cable capacitance. The maximum cable length specified by the standard is 17m corresponding to a data rate of 20kbit/s, but up to ten times this rate is possible over shorter distances. However, RS-232 is vulnerable to electrical interference (Lipman, 1997), which can corrupt the transmitted data. This can be minimized by keeping transmission cables short.

RS-422, RS-423 and RS-485

RS-422 is used in situations where long distances are required, it can drive up to 1200m at 100kbit/s, and up to 1Mbit/s over short distances. RS-422 uses a different driver, uses a four-conductor cable, and up to ten receivers can be used as a direct substitute for RS-232 in many cases.

IEEE-488 (GPIB)

General Purpose Interface Bus (IEEE-488) comprises 8 data lines, 8 control lines, and 8 ground lines. Up to 15 devices can be interconnected on one bus. Each device is assigned a unique primary address, ranging from

4 to 30, by setting the address switches on the device. Devices are linked in either a daisy-chain or star (or some combination) configuration with up to 20m of shielded 24-conductor cable. A maximum separation of 4m is specified between any two devices, and an average of 2m over the entire bus. The data transfer rate can be up to 1Mbyte/s.

IEEE-1394 (FireWire)

The IEEE-1394 defines a serial interface that can use the bus cable to power devices. Although it reduces the attached devices need for AC-line-operated power supplies, many instruments require more power than the bus can deliver. Fire wire transmits data in packets and incurs some overhead as a result. Devices have the option of using an isochronous mode, which guarantees the devices a time slot for data transfer in every frame. FireWire frames are 125msec long which means that despite a 'headline' speed of 400 Mbit/s, FireWire can be substantially slower in responding to instruments service requests. Another problem with using the isochronous mode for test and measurement application is that it doesn't guarantee lossless data transmission.

USB (Universal Serial Bus)

USB has many features in common with FireWire: serial data transmission, device powering, and data sent in 1ms packets. USB offers 1.5 and 12-Mbit/s speeds. Individual devices can use the bus for a maximum of 50% of the time. In practice, the maximum rate is not more than 0.6 Mbyte/s, which is lower than IEEE-488's 1-Mbyte/sec maximum, but fast enough to substitute for IEEE-488 in more than 80% of instruments.

Ethernet (TCP/IP)

Instruments with Ethernet interfaces have the great advantage that they can be interrogated and controlled from a desktop anywhere in the world. A 'web enabled' device behaves like a website and can be operated with standard browser. Systems based on these devices can make use of existing Ethernet networks and connecting an instrument directly into the internet makes sharing of data easy. Fast data transfer is possible, at up to IGB/s if the network infrastructure is good. However, it is very difficult to secure any device connected to the public internet and extreme caution and a full evaluation of the risks involved is essential in every case (Williams, 2003).

CONCLUSION

Computer-Based Instrumentation is fueled by ever-advancing computer technology and offers the power to create and define a system based on an open framework. This concept not only ensures that work will be individualized and usable in the future but also provides the flexibility to adapt and extend as needs change. This study was carried out with scientists and engineers in mind, providing powerful tools and a familiar development environment created specifically for the design of computer-based instruments.

A wide variety of transmission and communication techniques are available to process control and instrumentation engineers. As a result, it will be necessary for instrument and process engineers to understand the main principles of communication to ensure integration into process control systems and into the industrial environment is facilitated to enhance industrialization.

REFERENCES

1. Williams, C.D.H. 2003. "Computer Interface for Instrumentation Systems". University of Exeter: UK.

2. Davis, S. 1998. "EMI; Digital Designer's Nightmare". *Computer Design*. 37(1).

3. Encyclopedia Britannica. 2004.

4. Finkel, J. 1975. "Computer Aided Experimentation". John Wiley and Sons, Inc.: New York, NY.

5. http://www.microlink.co.uk/dataaq.htm

6. http://en.wikipedia.org/wiki/industrialization

7. Lipman, J. 1997. "Tools And Techniques Stifle EM Emissions". *EDN*. November 6, 1997.

8. Ott, H.W. 1998. *Noise Reduction Techniques in Electronics Systems 2nd Edition*. John Wiley and Sons Inc.,: New York, NY.

9. Matthew, P.R. 1982. *Communication In Process Control.*

10. Loxton, R. and P.Pope. 1993. *Instrumentation*. Springer: New York, NY.

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