Sensors with a direct connection to the Internet

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Abstract: - This paper deals with utilization of the Ethernet interface, TCP/IP protocols and Internet protocols and technologies at the lowest communication level – „sensor bus“. The questions of power supplied to the sensors via Ethernet interface (according to the IEEE 802.3af standard), mechanical configuration of the connectors and electronic circuits, including selection procedure concerning suitable processor, are discussed. The next part of the paper deals with description of the experimental module for embedded Ethernet interface mounted into the standard sensor's body. This description also includes software equipment consisting of web server, server of the application protocol Modbus/TCP, server for configuration and user application for processing of measured data. Finally, the world's first pressure sensor with a direct connection to the Internet is described.

Key-Words: - Internet, smart sensor, Modbus TCP, power over Ethernet

1 Introduction

Thanks to suitable properties, the Ethernet (IEEE 802.3) communication interface is the most widely installed local area network (LAN) technology. The cost of the Ethernet components is gradually decreasing while transmission rate is increasing. Ethernet is naturally compatible with the Internet technologies and it is widely used (with TPC/IP protocols in transport layer an network layer) in offices, laboratories and technical and technological divisions. Therefore Ethernet interface attracts area of industrial automation.

The Ethernet has been widely used for above mentioned communications, but lacks real-time communication capability in systems for real-time control. The real-time communication refers to communication to be finished within a specified time span, or in another word, that imposed with a deadline. Today, the switches break up collision domains into single devices, effectively reducing the number of collisions to zero if every Ethernet device uses dedicated port at the switch. It enables to use Ethernet (electromechanical version for heavy industrial environment) as an industrial communication system – Industrial Ethernet. Industrial Ethernet is used for communication between different hierarchical control levels, as well as between elements and systems at first control level (PLC, industrial PC, complicated embedded devices and data concentrators, detached discrete and analog IOs).

However, it has not been used at sensor bus level, until now. Use of Ethernet at the lowest communication level increases transparency of the communication from the highest communication levels to the level of individual sensors and control elements without usage of gateways for protocol transformation.

This paper exemplifies development of such device on the example of world's first pressure sensor (SEN 2000P) with embedded Ethernet interface.

SEN 2000P was developed in the cooperation with leading Czech producer of barometric instrumentation BD Sensor Ltd. and under the support of Grant Agency Czech Republic. SEN 2000P includes Ethernet interface and web server for projecting, parameterization and monitoring via Internet.

2 Issues of the embedded Ethernet interface in sensors

As it was mentioned before, direct connection of sensors and actuators on the Ethernet eliminates usage of gateways for protocol transformation. However it brings another issues:

- sensor's power supply,
- robust version of the Ethernet connector,
- dimensions of the embedded electronic,
- cost.

Ethernet has higher power consumption in comparison with the other communication standards and interfaces (Profibus, DeviceNet, Foundation Fieldbus, LonWorks, CAN, Interbus, AS-interface, etc.). However, thanks to the new IEEE 802.3af [1] standard, Ethernet allows to supply power to the stations with the power consumption less than 12.5 W (sensors with direct Ethernet interface and another embedded systems) similar to the other industrial buses. Power supply is realized either utilizing an inactive pair in the Ethernet cable CAT5, or directly along the signal line. Part of the 802.3af standard defines automatic recognition if connected device is with the 802.3af. If not, then Ethernet power supply, named PSE (Power Sourcing Equipment), obviates to connect up power voltage to the cable, which protects incompatible elements. 802.3af standard also manages power supply PSE and it can warn the system of network management that one of the connecting devices has a problem.

Problems with the Ethernet connectors for the industrial environment are solved either by a standard RJ45 connector (protection IP 25), or by RJ45 connectors with higher protection (IP67) [2], [3], [4]. As not all connectors produced by different manufactures are 100% compatible, another solution is connector M12. This connector is a standard for a lot of sensors and industrial networks. The advantage of this sensor is low failure rate and therefore high reliability in industrial application. Dimensions of the M12 connector are convenient to install it into sensor's body. This connector is recommended by ODVA organization for Ethernet IP protocol and is also accepted by IAONA organization. That's why it is more appropriate than RJ45 for industrial Ethernet applications.

Dimensions of the embedded electronic must meet sensor's body dimensions. Electronic must include processor for signal processing and protocol TCP/IP generation. It must also include RAM and ROM memory for communication protocol, for user program and Ethernet driver. All these elements are already on the market in the form of miniature processors with fully integrated Ethernet interface (e.g., Ubicom IP 2022).

Another important requirement is the price of the embedded system. According to some European producers of the embedded devices, at least one Ethernet interface for 8 Input/Output items is profitable. Nevertheless, producer of the SEN 2000P and author of this paper are convinced of the fact that even single highly accurate pressure sensor with the Ethernet interface and implemented web server will be demanded on the market in a short time.

3 Development of the sensors with Ethernet interface

Brno University of technology (BUT), Faculty of electrical engineering and communication (FEEC), Department of Control and Instrumentation (UAMT) cooperated with company BD Sensor Ltd. between years 2002 and 2003. The result of this cooperation was universal electronic module for standard pressure sensors that were in business plan of the above-mentioned company. This module accelerated development of the sensor with the Ethernet interface. The cornerstone of the module is microprocessor IP 2022 (Ubicom company) [7]. IP 2022 is very fast (120 MHz) RISC processor with 64 kB Flash memory and 20 kB RAM memory. This processor does not realize HW circuits for Ethernet interface, however it is possible to realize SW version of the 10Mb/s Ethernet. It predestinates this processor as the most convenient control element for sensor with Ethernet interface. Some similar processors (e.g., Dallas 80C400, IPC@CHIP, NET+ARM) have not significant advantages in comparison with IP 2022. Contrary, important parameters of these processors (dimensions, price, price of development system) are drawback. To increase memory space of the module, another serial Flash memory (512 kB) was added. This memory is used for process data, web server and memory space for user program. The module is also equipped with 16/24 bits AD converter AD 7714. The module is compatible with the 802.3af standard and it is powered through Ethernet cable. Realization of the module is shown in Figure 1. Connection is made by industrial version of the RJ45 connector – protection IP 67.

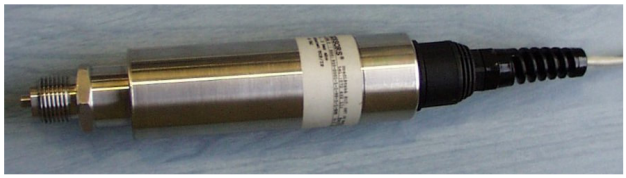

Fig 1. Final product – Industrial grade pressure sensor with Ethernet interface

3 Development of the sensors with Ethernet interface

Major advantage of the Ethernet interface and TCP/IP protocol suite is the possibility to utilize vast amount of available application layer protocols above TCP/IP. Thanks to this technology it is possible embed into a device support for protocols like http, ftp, smtp. From the industrial protocols it

is possible to utilize Modus/TCP, Ethernet IP, ProfiNet, OPC-DX, etc.

The universal module at present supports two application layer protocols – http protocol for configuration and visualization. Welcome screen of the user interface is shown in Figure 2. Second application protocol is the Modbus/TCP, which is well supported by OLE and DDE.

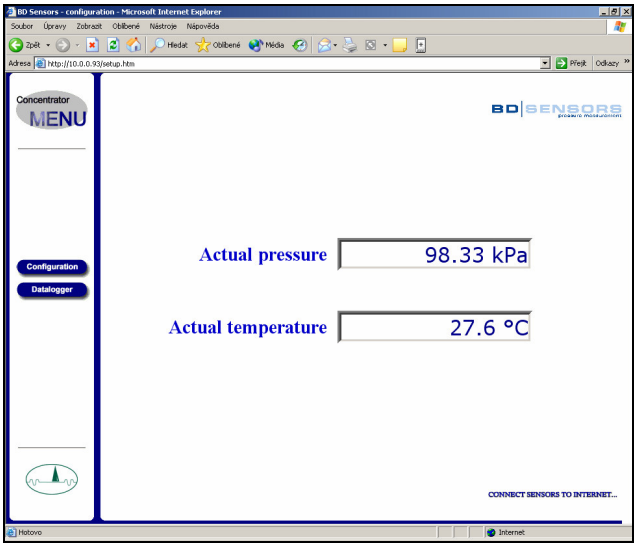

Fig 2. Welcome screen of the sensor

4 Design of pressure sensor with Ethernet interface

Based on development described above a prototype pressure sensor SEN 2000 P with Ethernet interface has been developed in cooperation with BD Sensors Ltd. The development of SEN 2000 P was possible through combination of analysis of needs, requirements, available technologies together with know-how of the BD Sensors in the field of development and production of pressure sensor.

Technical characteristics of the SEN 2000 P sensor are shown in the Table 1.

Firmware of the SEN 2000 P consists of:

- Code taking care of measurements of the pressure and temperature;
- Web server;
- Modbus server;
- Configuration server.

Web server of the SEN 2000 P provides static data (HTML fields, figures, Java applets), which are stored in the Flash memory. Moreover it provides dynamical data that are generated during run time (CGI scripts).

Modbus TCP server supports two most general Modus commands (Read multiple register a Read input registers) and allows for bi-directional data transmission between the sensor (server) and client (PLC, IPC etc.) based on Modus/TCP protocol, which is a standard variant of the well known Modbus protocol.

CPU:	IP2022, RISC 80MHz
FLASH memory:	1MB
Pressure sensor:	
Range:	0 - 350 Pa to 0 - 250 MPa
Resolution of ADC:	16 bits
Sampling period:	100 ms
Temperature sensor:	
Range:	-20 to 80 °C
Accuracy:	±1 °C
Sampling period:	100 ms
Ethernet 10BaseT interface:	
Transmission speed:	10 Mbps
Connector:	Industrial RJ-45 with IP67
Protocols:	HTTP, Modbus/TCP
Datalogger:	
Capacity:	up to 64 000 records
Storage period:	1 s to 40 days (step 1 s)
SPARE:	Function limiting recording based on comparison of value with predefined thresholds
Package:	Stainless steel
IP protection:	IP67
Operating temperature:	-40 to 85 °C
Storage temperature:	-65 to 150 °C
Dimensions [mm]:	∅39,5 × 146
Supply voltage:	44 to 57 V according to IEEE802.3af
Power consumption:	1,2 W (max) 0,8 W (power save)

Table 1. Technical characteristics of SEN 2000 P pressure sensor

User interface of the sensor is based on the web interface realized by the embedded web server. The internal web server enables to configure the senor, monitor actual values of the pressure and temperature. Also it allows listing out recorded historical data from the database in the form of lists or charts. Data in the XML form are available as well to enable easy interconnection to high-level system.

For correct operation following software on the client side is needed only:

- Internet Explorer version 6.0 or Mozzila version 7.0 with enabled support for Java and JavaScript;
- Java Sun plug-in version 1.4 or better.

Configuration server is used for configuration and setup of parameters of the sensor. Communication is based on UDP broadcasts. Configuration is based on user application supplied by the vendor of the sensor.

5 Conclusion

In the frame of project "Sensvision – direct connection of sensors to Internet", supported by Ministry of Trade and Industry of the Czech Republic, a set of devices with Ethernet interface and support for Internet protocols had been developed. This paper presents results of research and development in the field of process instrumentation with embedded Ethernet that supports of state of the art technologies (Internet, Java & JavaScript). In the frame of design and development of the pressure sensor challenges concerning electro-mechanical construction of the sensor like industrial grade connectors for Ethernet, special power supply circuitry according to IEEE 802.3af, heat dissipation and power consumption had been faced too.

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