Abstract: - This paper describes some issues which have to be addressed when developing a sensor with embedded Ethernet interface. The paper discusses a industrial grade Ethernet connector, suitable power method and some other topics. An example of such developed sensors is described.

Key-Words: - sensor, Ethernet interface

1 Introduction
The popularity of Ethernet as an industrial communication bus is constantly increasing. However the original concept of the Ethernet, which was developed during seventies of the last century as communication technology for “office applications”, has to face some issues specific for industrial applications. The concept of the Ethernet proved to be very successful and encountered issues are being addressed by modifications and extensions of the most popular 10/100 BaseT standard.

2 Ethernet in an automation device
If the Ethernet has to replace traditional fieldbuses it has to provide features which are standard among the fieldbuses.

Traditional 10/100BaseT Ethernet, when compared to standard fieldbuses, lacks following features:

• Industrial grade connector with IP rating above the “office level” of protection. (Industrial applications usually require IP rating from IP45 to IP67, while the standard RJ45 connector has rated to IP20)
• Ability to power distributed sensors, small actuators and active network infrastructure from the bus (like DeviceNet or AS-interface).

Moreover the designers of automation equipment have to face following challenges when building Ethernet into automation devices:
• Size of components
• Power consumption and heat build-up
• Industrial grade Ethernet components

2.1 Industrial grade connector
There are basically two alternative solutions of this problem: a modified RJ45 connector as well as a M12 (micro-style) connector. There exist at least three RJ45 style IP67 solutions. Each of them is developed and supported by different group or company ([2], [3], [4]). As a result there are three solutions incompatible with each other.

The M12 connector has been used for long time industrial applications. This connector is a standard not only for sensor connections but also for the various fieldbus systems. The essential feature of this connector is the very low failure rate and hence the high reliability of the manufacturing plant. Another very important asset is the smaller footprint of the M12 connector compared to a sealed RJ45 solution. The M12 style connector [5] for industrial Ethernet application is proposed by ODVA (Open Device Vendor Association) for Ethernet/IP protocol and accepted by IAONA (Industrial Automation Open Networking Alliance). This type of
connector is more suitable for Ethernet sensor than the RJ45 solutions.

2.2 Power over Ethernet
The Ethernet interface components have higher power consumption compared to other standard fieldbus interfaces. Also the utilization of Ethernet interface leads to utilization of faster and more powerful microprocessors with larger memories when compared to standard fieldbus interfaces. However the development of IP telephony resulted in a standard defining distribution of power over Ethernet. This standard is suitable for both IP telephony and automation as it is able to provide sufficient power for majority of automation equipment.

The standard was developed by IEEE consortium as the 802.3af one [1]. Although this initiative was originally driven by the need of IP telephony, but it can be used to power any device with power consumption less than 12.5W. Although the standard was approved recently (June 2003), many manufactures already provide products and components adhering to this standard.

The above-mentioned standard defines the concept of power transfer for both 10BaseT and 100BaseT Ethernet, however the gigabit version is not supported, since it is not supposed to be used in the field of automatic control.

The proposed standard defines two forms of power insertion. The first one uses the spare pairs (4,5-7,8) of the CAT5 Ethernet cable to insert power – midspan solution. The power can be inserted either directly on the active network element or using an external device connected between the active network element and the powered device. The midspan solution allows to upgrade an already existing network infrastructure. The other way is to transfer power over signal pairs (1,2-3,6) of the CAT5 cable. The signal transformer of the powered device (PD) will separate the power and data signal.

In order to prevent damage of the network devices not supporting the POE, the 802.3af standard defines a “resistive signature” detection mechanism. Before applying the full power, the power supply (PSE) sends a discovery signal to the device, which detects POE enabled device. Only if such device is discovered, the full voltage is applied. The power according to the 802.3af is max. 15.4W (44V–57V DC) on the PSE side, which yields approx. 13W for the PD side.

The standard 802.3af also defines SNMP management of the PSE and it can alert a network management system if a device is in trouble.

2.3 Size of components
The hardware of the device with Ethernet interface has to include three main parts: a processor with sufficient performance to handle high data rates of Ethernet and TCP/IP communication, adequate amount of memory – both RAM for data and ROM for program and an Ethernet controller with Ethernet physical layer. In the worst case this means a system with four chips and complex printed circuit board, which of course results in bigger size of the whole system. The available space for the electronic components is usually very limited in a sensor or actuator, so the size of the system is crucial. To realise the sensor, it is necessary to use some solution, which utilizes components that integrate more functions in single chip. The ideal solution integrates all components in one chip, however such solutions are usually limited as for features, flexibility and extensibility. On the other hand, such integrated solution means lower price, lower complexity and higher reliability.

2.4 Power consumption and heat build-up
The Ethernet components that are used in standard personal computer network interface cards (NICs), are not optimised for space, nor for low power consumption. The personal computers are well-vented devices and heat build-up caused by NICs is not a major problem as there are more significant heat sources in the computers. However the automation devices with high IP ratings have to be totally enclosed and exchange of heat is reduced, as there are no fans and no exchange of air between interior and exterior of the devices. The power low power consumption might became a crucial challenge not due the need to get enough of power to supply the device, but due the need to limit produced heat as that might lead to overheating of the device. The Ethernet components are usually available for temperatures up to +85°C. However the customers in the industry require the final devices to operate in high temperatures too. The margin for heat build-up in devices is very small.

3 Realization of a universal module
In order to be able to quickly develop a range of sensors with embedded Ethernet, a universal sensor module has been developed by authors. This module was developed in co-operation with BD Sensors Ltd.

The module is based on IP2022 microprocessor [8]. This microprocessor is a very fast RISC processor (up to 120 MHz), which has embedded 64kB Flash and 20kB RAM memory. Although it doesn’t have integrated hardware Ethernet controller on the chip, it has some special peripherals, which in combination with the high speed of the processor enable to process 10 Mbit Ethernet protocol in software. These features make it the best choice for this purpose. There are other systems on the market, which integrate some or the all parts in one
chip (e.g. Dallas 80C400, IPC@CHIP, NET+ARM), but none of them fulfils all the needs.

Although the IP2002 integrates 10-bit A/D converter on the chip, the sensor module uses external 16/24-bit A/D converter AD7714. The converter features five pseudo-differential (or three fully differential) input channels, programmable gain for each input channel and low pass filter.

To extend the memory space of the module a serial flash memory was added. It has the size of 512 kB and can be used to either store measured data, content of a web server or program code for the processor.

The module is 802.3af standard compatible and is powered via the Ethernet cable.

![Image of the realised module, size 67x35mm](image)

4 Software of the module

One of the benefits of the Ethernet and TCP/IP protocols is the possibility to use several application protocols above the TCP/IP. There is wide range of available solutions. It is possible to use some standard Internet protocol – http, ftp, smtp – or some special industrial application protocol – Modbus/TCP, Ethernet/IP, Profinet, OPC-DX, etc.

The situation with industrial application protocols is similar to the situation in the area of traditional fieldbuses. There are several of them proposed by different organisations or manufactures. Many of them are proprietary or semi-open, usually derived from traditional fieldbuses. There is not yet one generally accepted standard – war of fieldbuses continues on the new level.

There are used basically two application protocols in the module. The first one is http protocol used in www – the module contains embedded web server. The second protocol is an industrial application protocol Modbus/TCP. This protocol was chosen because it’s completely free to use without any licence fee and is widely used and supported by other tools (OPC, DDE, ...).

Because the module has available flash memory, the software of the module provides option to store measured data in the flash memory. The database system is configurable over the web server. A user can define two databases with different properties – size, sampling time, etc. A so-called spare function is available – the user specifies a condition and when the condition is met the system will store only some of the measured data (it can spare the memory space). The web server can be also used to display the stored data, either in the form of a table or graph (uses Java applet). The web server can be easily used to provide data as a xml file, which can be very easily processed by standard database tools.

5 Conclusion

Based on the previously described module a pressure sensor was realized. This sensor can be used either standalone, or integrated in some higher control system.

The disadvantage of the described solution is its limitation to only 10 Mbit Ethernet version. The 100 Mbit version would require Ethernet controller implemented in hardware, no current microcontroller can handle it in software. However the availability of similar system with embedded 100 Mbit Ethernet is only matter of time.

Currently only http and Modbus/TCP protocols are available for the sensor. However the system offers potentiality to further development. There are two industrial protocols being developed, which can aspire on the general industrial application protocol – a protocol developed by OPC Foundation based on the xml services – OPC-XML and protocol developed by IDA (Interface for Distributed Automation).

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References: