ADAPTER MODULE FOR ETHERNET NETWORK COMMUNICATION OVER TCP/IP

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For controlling and monitoring the electrical power system, it is needed to be stored and computated the data for many electricity parameters measured in different points of the electrical system. In many cases it is needed the information for every parameter, to be sent to a monitoring and visualization main-system device, which is usually situated on a long distance from the basic measuring module.

1. BASIC FEATURES OF THE PROJECT

For controlling the quality of the electricity, it is needed to be measured as many parameters as possible from different points of the network. The main goal of this project is to be designed technical equipment for transfer the measured values from the intelligent measuring modules to the main-station server through Ethernet.

Experimentally will be tested as prototype for monitoring the parameters of the electricity on the territory of Technical University of Sofia. For basic power conversion modules will be used intelligent sensors designed by Development Laboratory for Semiconductor Circuit Engineering (http://www.tu-sofia.bg/r&ds/PS/home.htm) at Technical University of Sofia. The most appropriate of these devices is the intelligent measuring sensor for voltage, current, frequency, active and reactive power – PST08, which is designed for measuring the basic parameters of the four-wire three phase systems with accuracy of 0.1%. PST08 has one serial digital interface and 3 analog current interfaces ±5mA. The idea is to be used the integrated digital interface for transferring the data from the intelligent modules to the main station.

The integrated serial digital interface in PS intelligent modules gives the possibility network connection between them and a Personal Computer. This connection is based on RS232 interface and the maximum devices connected to on RS232 port of a PC is 10. The maximum speed of transfer is 9600 bps, and the physical connection is made through adapter (Fig. 1a).

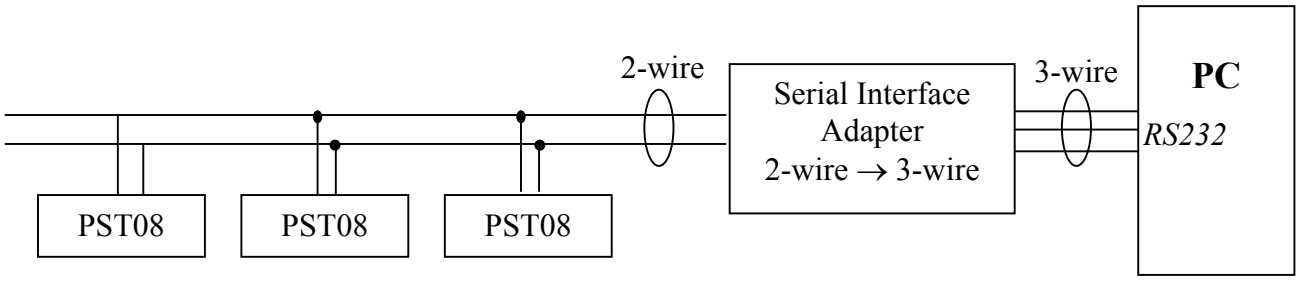

Fig.1a Network communication between PST08 and PC, based on the serial interface integrated in the intelligent sensors

The Ethernet communication interface gives the possibility to connect many of the modules in network again by using interface adapter (Fig. 1b). This network permits transfers of data with 10Mbps.

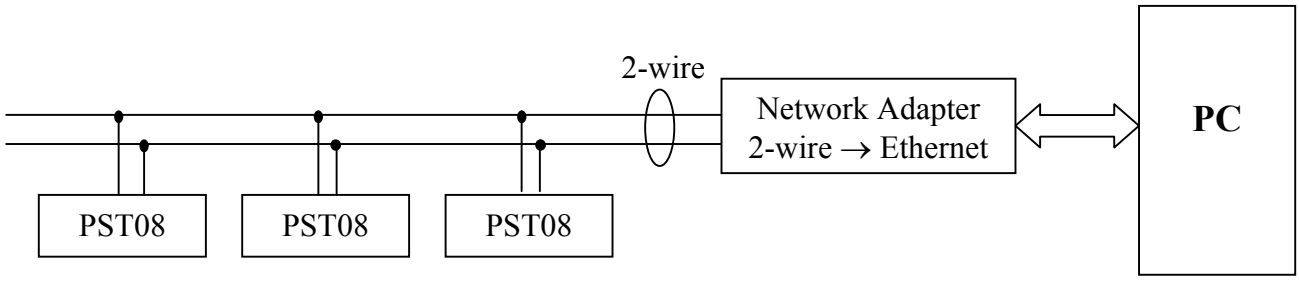

Fig.1b Ethernet network communication between PST08 and PC, based on the serial interface integrated in the intelligent sensors

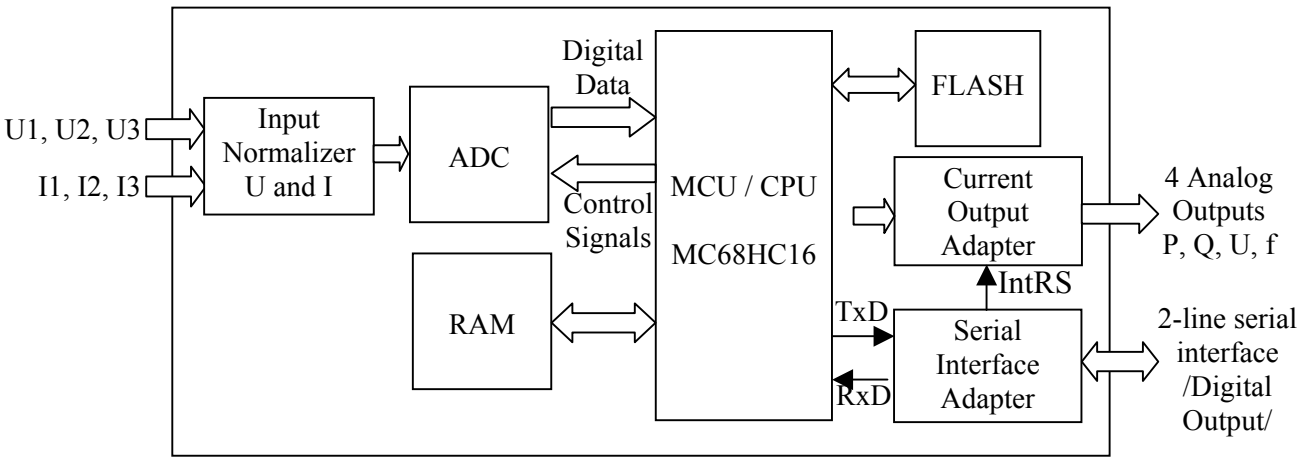

Fig.2 Functional Block Diagram of PST08

Fig. 2 shows the functional block diagram of PST08. This device contains the basic hardware modules needed for normalizing the input analog signals for three-phase electricity systems, converting the normalized analog signals to digital data by integrated ADC, making the basic computations with the MCU block and storing the results in RAM memory, and transfer all the results to 2-line serial output. There is also Analog Interface, which gives analog values for P, Q, U and f parameters of the electricity.

The 2-line serial interface has the following data transfer protocol:

The transfer begins when the main station sent command, in other case PST08 does not send data through serial interface.

The bytes generated from the main station have MSB – '1'.
The command row contains: 11xx xxxx, 10xx xxxx
/address/ /command/

The command row is received from all intelligent sensors connected in the network. The sensor which number is the same as the address in the command row is giving a reply. The bytes send for reply have MSB - '0'.

The reply contains:
00xx xxxx, 00xx xxxx, 0xxx xxxx, 0xxx xxxx, 0xxx xxxx
address, command, number of bytes, data, check sum

When the sensor receives command $02 (data from the measurement), the reply is:

Byte Number:	Content:	Byte Number:	Content:
0	**Address**	**17, 18**	**Q_{MS}, Q_{LS}**
1	**Command**	**19, 20**	**Fст, Fмл**
2	**40($28),**	**21 - 32**	**reserved**
3, 4	**$U1_{MS}$, $U1_{LS}$**	**33, 34**	**φU2a, φU2b**
5, 6	**$U2_{MS}$, $U2_{LS}$**	**35, 36**	**φU3a, φU3b**
7, 8	**$U3_{MS}$, $U2_{LS}$**	**37, 38**	**φI1a, φI1b**
9, 10	**$I1_{MS}$, $I1_{LS}$**	**39, 40**	**φI2a, φI2b**
11, 12	**$I2_{MS}$, $I2_{LS}$**	**41,42**	**φI3a, φI3b**
13, 14	**$I3_{MS}$, $I3_{LS}$**	**43, 44**	**CS1, CS2**
15, 16	**P_{MS}, P_{LS}**		

U1, U2, U3; I1, I2, I3 – 2 bytes binary code for values of phase voltage and phase current received at the sensors' input

P, Q - 2 bytes additional code for values of the active and reactive powers in relation to the input of the sensor

F – Binary code for the value of the voltage frequency at the input of the sensor

Ku, Ki – 2 bytes binary code for the value of initiated in the sensor coefficients of transformation of the measuring transformers

φU2, φU3, φI1, φI2, φI3 – 2 bytes binary code for the value of the voltage and current phases at the input of the sensor

CS – check sum – 2 bytes binary code /0aaa aaaa, 0bbb bbbb/ for the sum of all bytes – from the firs one (the address) to the last one (φI3б)

The main disadvantages of the integrated digital serial interface in PST08 sensors refer to the impossibility of transferring data on a long distance. On the other side,

this protocol is simple, but also non-standard. Besides that, the personal computers in now days don't have serial interface as integrated one and it is complicated to develop a network through RS232 interface, which is replaced by USB. Base on these facts, it is decided to be used a new modern approach for network connection.

2. BASIC FEATURES OF THE ADAPTER BOARD FOR NETWORK COMMUNICATION

For realization of network connection between PST08 sensors and a PC, without making changes of the electrical circuit of the sensors, the only decision is to be used the digital serial interface integrated in the intelligent modules, but the data from it to be converted to another protocol suitable for transferring data faster and on a long distance. After this conclusion, it was decided to be designed an adapter module for converting the serial data into Ethernet packets. The Ethernet network is now very popular and it is not expensive to be made. The basic components needed for developing this kind of communication is an Ethernet controller, HUB or Switch and the physical connection – UTP/FTP cable and RJ45 plug and connector. After the investigation, it was made a conclusion that it is appropriate to be used RTL8019 integrated circuit produced by the Taiwan Company **Realtek**. This Ethernet controller is intended for 10Mb/s networks with 8-bit ISA interface. For controlling this IC it is needed an 8-bit data signal, address signals and IOW, IOR and Reset signals. IOW and IOR signals are for allowing writing and reading to/from the RTL8019 registers. For this purposes it is very convenient to be used an 8-bit Microcontroller for realization of the physical and software interface between the serial data from the sensor and the Ethernet controller. For 8-bit microcontroller is chosen the PIC16F877 MCU produced by Microchip. This MCU has enough I/O pins for the purposes and its program FLASH memory and data EEPROM memory are enough for development. The main purpose of the microcontroller is to collect data from the serial interface, to store them and after that to prepare Ethernet packets for sending through RTL8019.

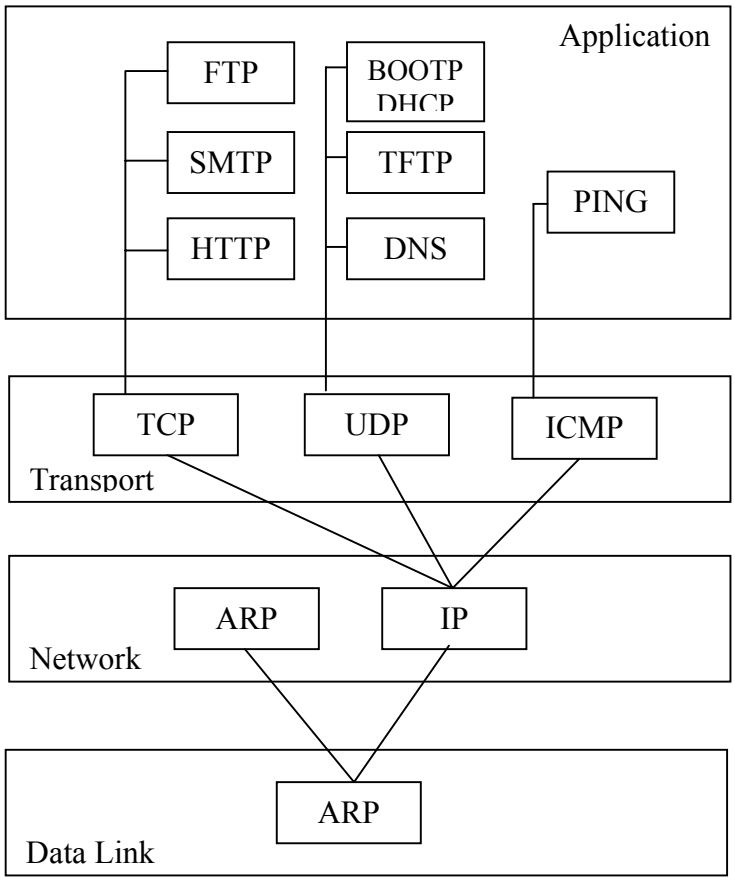

Fig.3 5-Layer network model

Fig. 3 shows the protocol layers for communication system. Data Link, Network and Transport layers are realized by the adapter module. On every layer there are different types of protocols.

The purpose of every layer is as follows:

	Name of Layer	**Purpose of Layer**
Layer 5	Application	Specifies how a particular application uses a network.
Layer 4	Transport	Specifies how to ensure reliable transport of data.
Layer 3	Internet	Specifies packet format and routing.
Layer 2	Network	Specifies frame organization and transmittal.
Layer 1	Physical	Specifies the basic network hardware.

For transferring data over Internet Protocol it has to be observed the following rules:

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Version|  IHL  |Type of Service|          Total Length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Identification        |Flags|      Fragment Offset    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Time to Live |    Protocol   |         Header Checksum       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Source Address                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Destination Address                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Options                      |    Padding    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
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For communication over IP protocol every device in the network has own MAC (6 Bytes) and IP (4 Bytes) address. When two devices want to communicate the sender has to note source and destination MAC and IP addresses.

For communication over Internet Protocol, the minimal service is UDP, adding only optional checksumming of data and multiplexing by port number. TCP (Transmission Control Protocol) is a connection-oriented transport service; it provides end-to-end reliability, resequencing, and flow control. TCP enables two hosts to establish a connection and exchange streams of data, which are treated in bytes. The delivery of data in the proper order is guaranteed. TCP can detect errors or lost data and can trigger retransmission until the data is received, complete and without errors. But in this case it is needed more resource from the MCU placed on the adapter module.

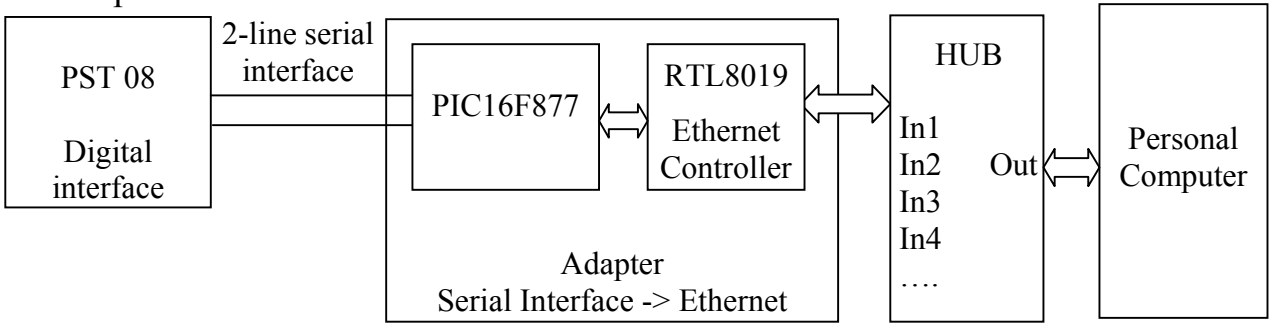

Fig. 3 Functional block diagram of the network system

The adapter module connected with PST08 is similar to **gateway,** which makes possible communication between two devices with different standards and protocols. In this case, a command is send from the main station in the network. Every adapter has an individual IP address, which corresponds to every intelligent sensor. It means that it is needed an adapter for every sensor. To be connected with a PC, the adapter modules have to be connected to HUB or Switch. The adapter module recognizes the IP address sent from the main station and it sends a command to PST08 for data request. The sensor begins transmitting data to the adapter, where the PIC16F877 stores the data in its data RAM memory. The microcontroller prepares the packets for transmitting to the main station through Ethernet over UDP protocol (first tests are over UDP) or TCP. The software on a high level, installed on the PC, helps for collecting, storing and visualizing data in convenient for the user way.

3. CONCLUSIONS

When two devices have to communicate on a long distance, Ethernet network is the best solution. It is very easy to design the hardware because of the ready to use filters, connectors and integrated circuits. The main problem is in software – mainly in realization and observation of all rules for Ethernet packets. Ethernet communication is fast enough, it gives a possibility for collecting, storing and visualizing data on a PC screen situated on a long distance from the destination points, in this case the intelligent sensors. For reliable connection it is recommended to be used TCP, but the UDP is also convenient.

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