AN OVERVIEW OF THE P-NET FIELDBUS

Produced by: The International P-NET User Organization *504500 02*

THE HISTORY OF P-NET

P-NET was conceived in 1983 by Proces-Data Silkeborg ApS Denmark. The first product using this multi-master fieldbus was launched in 1984. The multi-networking and gateway functions were added to the protocol specification in 1986. The first operational P-NET to P-NET gateway product (PD3000) was made available in 1987. In 1987, P-NET was adopted by Ultrakust Electronic GmbH, Germany, in the manufacture of their own network instrumentation. In the same year, a number of other companies, such as IPH in Denmark and FMA in the UK, began producing applications using the PC based, P-NET orientated, Process-Pascal cross compiler.

The P-NET standard was made an open standard in 1989, for the purpose of adoption worldwide. In 1990 the VDI/VDE Institute in Berlin made a comparison between various fieldbus standards available, and concluded that wider use of P-NET depended only on more companies/institu-tions knowing of the existence of this versatile protocol. Due to the great interest in P-NET, stimulated by the publication of the report, it was decided to form the International P-NET User Organization. The 1st International P-NET Conference took place in Denmark in 1991, and was attended by 40 delegates. The International P-NET User Organization will arrange an annual International P-NET Conference. In order to promote a greater knowledge of this fieldbus, it was proposed that the International P-NET User Organization would participate in the International Trade Fair - INTERKAMA 92, in Düsseldorf, Germany. Some independent companies exhibited their P-NET products on the stand, and demonstrated the interoperability between the various vendors' equipment, without prior arrangement.

History of the P-NET Fieldbus	
Work started	1983
Layer 1 through 3	1984
Layer 4 and 7	1986
Protocol testing	1984 - 1986
Products introduced and available	1984
Standard fixed	1987

The P-NET fieldbus has now been used for many years, and more than 4000 applications worldwide are already operational, each utilising the advantages of the P-NET protocol. Applications range from simple installations with about 20 I/O points, to very large and complex installations using more than 4000 I/O points. A video, with English or German commentary, shows examples of a wide variety of installed applications and is available from the International P-NET User Organization.

APPLICATION AREAS

The majority of P-NET applications are found in the process industry environment, but examples also appear in discrete parts manufacturing plants.

Some types of fieldbus applications demand a response time measured in µs. This high speed only makes it possible to transfer simple variables in bits and bytes, and the length of the physical bus is limited to a few meters with a restricted number of I/O points.

Other types of fieldbus applications, require response times measure in ms, and a bus length up to one km or more, and this is the type to which P-NET belongs. The variables, transferred on the bus can be more complex, and contain reals, arrays, records, bytes, strings, boolean etc, all with well defined types, to satisfy the requirements of measurement, control and analytical applications.

Input/Output counts can vary from a few, using a single master and one or more slaves, to several thousand, using many masters and many P-NET bus-segments.

Key aspects for the P-NET Fieldbus	
Number of Installations	More than 4000
Current range of I/O points in P-NET installations	20 - more than 4000
Speed of messages	Up to nearly 300 confirmed services per second
Bit rate	76.8 kb/s
Message Timing	Deterministic

PRINCIPLES OF P-NET

P-NET is a multi-master and multi-net standard. All communication is based on a principle, where a **Master** sends a request and the addressed **Slave** returns a response. Not only can several masters be connected to each bus segment, but a complex network holding a great number of bus segments can be built also.
Communication is routed through the different bus-segments by means of gateways[1] with two or more P-NET interfaces. This means that any master on the network can transparently access any node within the network without the need for special programs in the gateways or masters. This feature is a part of the P-NET protocol and is built into the standard operating system.
The segmentation also makes it possible to have independent local traffic on each bus-segment, which increases the data throughput throughout the total system.
These multi-bus features, provide a natural redundancy and makes the total plant installation very robust with respect to errors. A system can be expanded while the remaining production systems continue to run. It is a feature of the P-NET topology that it need not be of a hierarchical structure.
An example of a slave could be, a weight transmitter, where the analogue signal from a built in or remote load cell, is continuously converted, scaled and stored within the memory of the slave. When a request is received from a master, the slave will immediately respond with the latest stored result. Error checking is also continuously performed within the slave, and the master is notified if an error has occurred, within any response message. Using this principle, it is thus possible to respond immediately to a request from a master, to read or write measurement or other data in a slave. A slave must return the response to the master within at most 390 µs following the master's request.
This reduces the need for multiple requests for a single variable, or even continuous polling until a result is ready. The immediate response eliminates the need for buffers to queue the requests or polling from different masters.
Special procedures have been included in the P-NET standard, making it possible to change the node address of a single node on the network by means of its unique serial number. This gives the opportunity to set-up node addresses to individual P-NET nodes, while the system is running. A node is delivered with the node address set to zero, and this node address is reserved in the standard for the purpose of initializing nodes while the network is running. Dipswitches and other mechanical mechanisms can thus be avoided, because the serial number is stored in EEPROM. Using an EEPROM makes it possible to build hermetically sealed P-NET nodes (e.g. IP-67).

[1] A Gateway within P-NET provides multi-network expansion at the Network Layer, and therefore messages can be sent transparently between P-NET segments.

EASE OF P-NET IMPLEMENTATION

The P-NET communication program for a slave may require as few as 2k Bytes. This provides the opportunity to use a common single chip micro-processor, with built-in EPROM facilities, which will then support not only P-NET communication but also measuring, calibration, conversion and application functions.

CHIP-SET: The P-NET Interface Chip is developed for making an easy communication interface to P-NET. Both multi-master and slave features are implemented in the P-NET Chip. The device performs all the functions of layer 2, the Data Link Layer, which includes the most time critical functions in P-NET. The P-NET Interface Chip controls the bus access, which includes both slave bus access and multi-master bus access, and synchronization of the bus. The P-NET Interface Chip creates and recognizes the frames on the bus and performs the transmission error control. The Network Layer and the Service Layer functions (Layer 3 and 4) are performed by software in the Host processor.

A development kit that includes the necessary interrupt-procedures and conversion-procedures for layer 3 and 4 are available with the P-NET Interface Chip.

These procedures are written in ANSI C and can therefore be included directly in a Host-program written in C. In case the Host-program is written in assembler, the C procedures can be used as a guideline for an equivalent assembler program.

NOTE: There is no need for a specific chip-set. P-NET nodes can be implemented using standard single chip processors i.e. Intel 8051, 80851, Motorola 6805, 68HC11, Hitachi 6301, etc., with built-in UART. This also leads to low development costs. Many years of experience has been gained in the implementation of P-NET nodes, and assistance is available to manufacturers through the International P-NET User Organization.

Key aspects for the P-NET Fieldbus	
Hardware Implementation costs	$5 - $20
P-NET chip-set	Chip-set samples available in 1994 from the International P-NET User Organization. The chip-set is not required, standard driver software available
Micro-processor requirements	8 bit processor
Manufactures of micro-processors for P-NET	All major vendors, e.g. Intel, Motorola, Hitachi, etc.

PROTOCOL OVERVIEW

P-NET is specified and implemented according to the Open Systems Interconnection Reference Model on layer 1, 2, 3, 4, and 7. The usage of the application layer (Layer 7) provides the plug-compability in relation to semantics, and the other layers provide the physical plug-compability.

Well defined application layer profiles for individual I/O points, gives a well defined Application Interface for programmers.

The I/O interfaces in the different nodes are defined as objects, which contain not only real time data but also predefined function switches, diagnostics, maintenance data and error messages. Within the P-NET Standard, such an object is declared as a **Channel**, and channel structures are defined for digital I/O, analog I/O, weight transmitters, printers, etc.

The standardization of the single I/O points instead of complete nodes on the P-NET makes it possible from a master's point of view, to exchange similar I/O's defined within different manufactures' nodes. Nodes can have different I/O structures. For example one node might have 16 Digital I/O + 2 analog I/O, and another node 8 Digital I/O + 4 Analog I/O, but a single I/O will be seen as the same by the master, no matter what kind of node it is part of.

Associated with the Application layer within P- NET, is the data format standardization, which includes reals, bytes, strings, boolean, but also more complex entities, as arrays and records. All measurement values sent over P-NET are already scaled in engineering units.

The Manufacturing Message Specification, MMS (ISO 9506) is used on layer 7, as an intelligent interface between

P-NET and other networks, (e.g. Ethernet, Token Ring, MAP, etc.) using a variety of protocols. A test installation is being developed for Ethernet with the Novell protocol. MMS provides a well defined interface between the field and the management area for software platforms, such as production planning, and monitoring system, at the management level. Typically, the MMS interface is used for non time critical communication. MMS is a well defined Application interface for software developers.

ADVANTAGES OF THE P-NET PROTOCOL

Slaves respond almost immediately after receiving a request. This requirement allows up to nearly **300 confirmed messages a second** to be made on the fieldbus. A confirmed service is a combination of a master request and a slave response.

The result of a measurement made by a slave is presented to a master in a pre-processed form, in SI (metrical) engineering units. The benefits within the masters, is significant, since no repetitive scaling or conversion need to be performed by the master(s), leading to considerable savings of processing power. The distributed processing power can be increased further, by adding masters, each of which allows several tasks to run simultaneously.

For example, a temperature measurement is represented by a floating point real value, following the IEEE 754 standard, and the temperature value is presented to all masters in centigrade. Identifiers used for accessing the physical variable on the network, are mapped via a 'softwire' list. This list is generated while the application program is being compiled. Therefore, no real time translation is required, leading to very fast data access.

Multi-master access to the Physical Layer is performed using a **virtual token** passing principle between masters. After a given master's bus access, the token is passed to the next master in a cyclic fashion. The maximum data length in one transmission is limited to 56 data bytes, for ensuring real time data collection.

The passing of the virtual token takes place within only 130 µS or 10 bit periods, and no data is actually sent over the bus. A single network can have up to 32 masters with equal priority.

Within multi-master and multi-net systems, all masters have equal priority, and there is no hierarchy which needs to be managed. Consequently, the P-NET does not require any arbitrator function. The virtual token passing is 5-20 times more efficient than software arbitration.

SOFTWARE

Process-Pascal is available as a program ming tool for P-NET controllers, which is Standard ISO-Pascal with additional facilities for declaring variables on the network, and for task management in a multitasking environment.

Programs written in Process-Pascal use global P-NET variables as if they were local variables, the only difference is to be found in the variable declaration technique. Multi-tasking facilities are also included in the Process-Pascal, and it is possible to have up to 64 tasks in each master.

P-NET drivers for PC based systems are available in Pascal, C and Modula 2, for DOS or Windows applications. Software tools for monitoring and debugging, as well as Graphic Control Systems are also available.

IS-16 INTRINSICALLY SAFE FIELDBUS

Electronic equipment for use in potentially explosive atmospheres, can be implemented using two principles:

1) Mounting the electronics in a flameproof enclosure, and including Zener-barriers on any outgoing unprotected wires. This can prove to be a heavy and expensive solution.
2) Using an intrinsically safe circuit. This is a circuit in which no spark can be generated, or any other thermal effect, capable of causing ignition in a given type of atmosphere.

A new physical layer IS-16 is under development for P-NET. The IS-16 Bus is an intrinsically safe bus for connection of intrinsically safe nodes. The nodes are **powered via the bus** from a safe power supply located in a non-hazardous area. IS-16 bus implementations are useful within non-hazardous areas as well.
Simple IS-16 sensors such as temperature sensors, pressure sensors, humidity sensors, etc. are likely to be more cost effective, as no galvanic isolation is necessary, compared to nodes which have a separate power supply.

INTERNATIONAL P-NET USER ORGANIZATION

The International P-NET User Organization is a non-profit making organization, and more than 50 companies are now members. The membership fee (1994) for companies is 1.500 DKK (≈ 400 DM or £160), and there are special arrangements available for universities and other educational institutions.
By enroling in the International P-NET User Organization, a new member will receive one copy of the P-NET standard, and has the right to use the P-NET protocol in products without any royalty.
The P-NET standard is available separately at a price of 400 DKK (≈ 100 DM or £40), and the VDI/VDE comparison study on Fieldbus Systems [Ref. 20] is available in German or English, at a price of 400 DKK (≈ 100 DM or £40). A video with English or German commentary showing examples of a wide variety of P-NET installations are available at a price of 320 DKK (≈ 85 DM or £35). To order the above mentioned material, please send a cheque in Danish Krones (DKK) to this address:

International P-NET User Organization
P.O.Box. 192,
Dk-8600 Silkeborg
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Local sections exist in Denmark, Germany and the UK, and bulletin board facilities exist for transfer of data and information.

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P-NET INFORMATION IN SHORT FORM

Communication between individual units of a distributed system of intelligent sensors and actuators, field and central controllers, gateways etc, requires a high performance, but economic, fieldbus. P-NET is the only fieldbus which has large scale implementations on a worldwide basis, and possesses the following characteristics:

HIGH SPEED
- Data rate of 76800 baud (cost / performance optimum).
- Extremely efficient protocol for all bus transactions. Up to nearly 300 confirmed services per second.

MULTI-MASTER CAPABILITY
- Up to 32 masters per bus segment.
- Simplified arbitration procedure (virtual token passing 5-20 times more efficient than software arbitration).

MULTI-NETWORK CAPABILITY
- Any number of P-NET bus segment can be networked using Controller Gateways (standard units) without further software expense.

NOISE IMMUNITY
- Electrical isolation between bus and electronics.
- Screened twisted-pair cable.
- Check-sum for data security (Hamming distance = 2, optionally 4).

ECONOMY
- Based on the RS485 standard, therefore uses standard components.
- Single chip 8-bit microprocessors provide sufficient performance, no need for chipset.
- 2-wire ring connection up to 1200 m long, dramatically reduces wiring costs.
- Up to 125 devices per bus segment.

HIGH LEVEL LANGUAGE SUPPORT
- Standard Pascal with extensions for multitasking and P-NET-access, reducing software expenses.
- Full support of all functions, including bus-segmentation capability, by means of the Process-Pascal cross-compiler.

IMPLEMENTATION EFFICIENCY

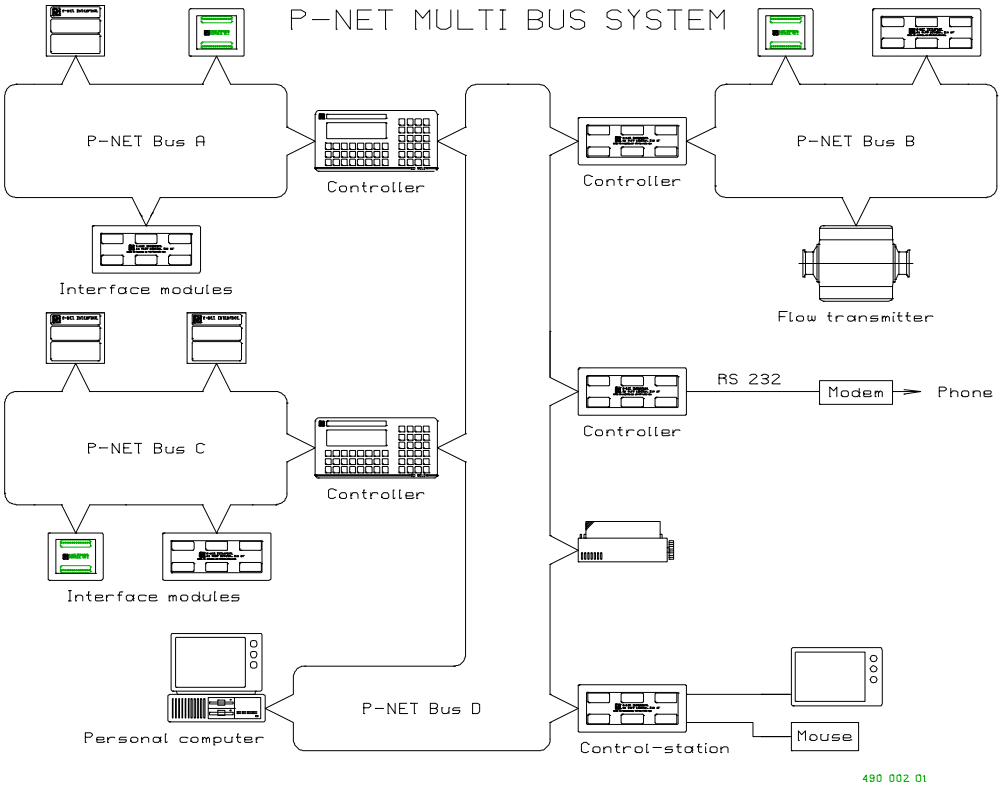
Compared to conventional wiring, P-NET offers proved advantages when applied to industrial processes, which result in simplification of
- Planning and installation
- Maintenance
- future expansion of industrial applications

DIAGNOSTIC CONTROL

The use of intelligent P-NET sensors and actuators offers diagnostic capabilities previously unavailable. Apart from the usual measurement values and status data, the bus provides a bidirectional exchange of additional information concerning limit values, actuator positioning and feedback, fault signals and internal system data. This provides new opportunities for efficient control of maintenance and system security.

P-NET USER ORGANIZATION

The International P-NET User Organization has more than 50 members worldwide. Some of the objects of the organization are
- to disseminate global knowledge of P-NET
- future development of the standard
- specify conformance test for products
- exchange info among the members



SPECIFICATIONS

Data transmission

Asynchronous transmission
Data in NRZ code
76800 bits/sec.
1 start bit, 8 data bit, 1 addr/data bit, 1 stop bit for each byte in the frame
Check-sum for data security (HD=2, opt. HD=4).

Capabilities

Up to 125 devices per bus segment
Multi-master, up to 32 per bus segment
Multi-net capabilities for nearly infinite expansion
ISO OSI 7 layers reference model
High level language support

Data types

Simple: boolean, byte, char, word, integer, longinteger, real, longreal, timer.
Complex: array, string, record, buffer.

Bus structure

A physical ring without termination.

Medium

Shielded twisted pair cable with minimum .2 2 mm² area conductors and characteristic im pedance of 100-120 ohm.

Bus length

max 1200 m (EIA RS 485).

Integrated transceiver

SN 75176A

Installation

The bus cable is connected from field device to field device, forming a physical ring. Modules may be changed 'live' i.e. no shutdown of the system is required.

Electrical specification:

LITERATURE REFERENCES

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