

## A LOW COST LOCAL AREA NETWORK FOR CONNECTING ACCELERATOR EQUIPMENT

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### Summary

For connecting accelerator equipment to an overall control system a field bus, the PDV-BUS (a German national standard, DIN 19241) is under evaluation. This standard was specified for industrial control systems and is now supported by a VLSI protocol chip. Our development is concentrated on a low cost station interface for connecting control equipment (pumps, magnets, etc.) and a driver board with a high level user software interface.

### Introduction

For the control of a linear accelerator (Spallation Neutron Source (1)) a hierarchically organized communications system is foreseen. For the top layer, a local area network is under discussion, which connects the central computers. A process highway network (PROWAY) serves as a backbone communications system carrying messages for the control of equipment, acquired data, status information, alarm messages etc. A token passing mechanism is preferred, in order to guarantee short response times. Field buses should connect the local control units in a cost effective way. The local control equipment can either be intelligent (microprocessor) or be realized by hardware logic only.

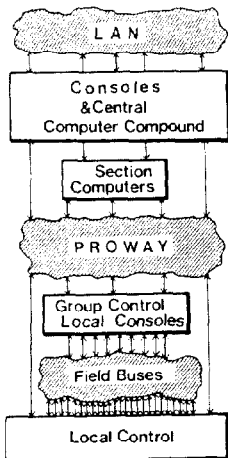


Fig. 1: Control System Structure

### The PDV-BUS (DIN 19241)

In Tab. 1 the candidate serial buses are summarized. Details are given in the literature (2) (3) (4). The PDV-BUS (an abbreviation of the German term Projekt Datenverarbeitung, a government sponsored project) is a German national standard, DIN 19241. It has been especially designed for the needs of process communication in distributed industrial control systems and therefore has been developed by some major companies with experience in this field. The protocol allows for up to 250 nodes on the bus. The bus arbitration can be centralized or be realized by a token passing mechanism, flying master scheme. The standard defines several protocol options, allowing e.g. direct read/write of 16 bit data words in one transmission cycle. This feature allows a direct communication on the lowest data link level with the distributed nodes without the intervention of local CPU power. It leads to a very efficient simple interface design with primitive equipment coupling via registers or Dual-Port RAM, where these devices hold the status, or read or write information of the connected equipment. This communication is signal and not message oriented as in normal local area networks. The necessary protocol functions for message interchange are also defined by the PDV-BUS standard, but presently not used in our application.

A transfer cycle on the bus line is performed in a command/reply structure so it is possible to imple-

ment the necessary functions of the error detection and recovery on the data link level. The Hamming distance equals 4, i.e. the PDV-BUS is able to cope with the harsh industrial environment. The physical layer gives some freedom to the designer, but the preferred solution is the transformer coupling of the line. This limits the achievable number of nodes to 100, also depending on the chosen cable type.

| FEATURES                    | BITBUS/INTEL<br>1) 2)       | D <sup>2</sup> -BUS/PHILIPS | MIL-STD 1553 B           | PDV-BUS                    |
|-----------------------------|-----------------------------|-----------------------------|--------------------------|----------------------------|
| Max. Number of Nodes        | 28 28 / (250) <sup>3)</sup> | 50                          | 31                       | 255                        |
| Data Rate (kbit/s)          | 500/2400 375 62.5           | 0.8 19.2 65.5               | 1000                     | 1000                       |
| max. Cable Length (m)       | 30 300 1200                 | 150                         | n.d. <sup>4)</sup>       | 2000 <sup>5)</sup>         |
| Transmission Medium         | Twisted Pair                | Twisted Pair                | Twisted Pair             | Coaxial <sup>6)</sup>      |
| Line Interface              | RS-485                      | Balanced                    | Transformer              | Transformer <sup>6)</sup>  |
| Bus Organisation            | Master/Slave                | Multimaster                 | Master/Slave             | Master/Slave <sup>6)</sup> |
| Data Link Service Classes   | Command (SDLC)              | Command/Resp.               | Command/Resp.            | Command/Resp.              |
| Data Encoding               | NRZ                         | NRZ                         | Manchester II            | Manchester <sup>5)</sup>   |
| Error Checking              | 16 Bit CRC/Package          | Parity Bit on 8 Bit         | Parity Bit on 20 Bit     | 8 Bit CRC on 16 Bit        |
| Hamming-Distance            | 2(4)                        | 2                           | 2                        | 4                          |
| Packet Size (max.)          | 231 Byte each 8 Bit         | 132 Byte each 11 Bit        | 33 byte each 20 Bit      | 390 Byte each 8 Bit        |
| Information Length (max.)   | 255 Byte each 8 Bit         | 128 Byte each 8 Bit         | 32 Byte each 16 Bit      | 256 Byte each 8 Bit        |
| Standard                    | NO (de facto ?)             | NO                          | YES                      | YES <sup>7)</sup>          |
| VLSI Chip                   | 8044                        | PCB 80 C 351                | COM 1553 B <sup>8)</sup> | MEE 3000 <sup>9)</sup>     |
| Functionality of the Chip   | High (programmable)         | High (progr.)               | Low                      | High                       |
| Price for Interface Chip \$ | 25                          | 20                          | > 120 <sup>4)</sup>      | 20                         |

1) Synchronous Mode  
2) Self Clocker Mode  
3) Using Repeaters

4) Not Defined, but 1553 A 300 feet  
5) Not Defined, typical  
6) typical but Flying Master too

7) DIN 19241 = German National Standard  
8) e.g. Standard Microsystems Incorporation  
9) Signetics

Tab. 1 Candidate Serial Buses

The stations are: Master Stations, which control the bus by granting bus requests from active slaves and perform the tasks of read and write operations. Also a master transfer capability can be implemented. Active Slave stations have all the functions of a master station apart from polling, granting requests and master transfer functions. But these stations can ask for the bus only for one transfer cycle (with error recovery). This type can be implemented in local consoles which for a given time have access over one or more peripherals. The Passive Slave station only responds to commands from a master or an active slave. All the equipment interfaces can be realized by this station type.

### The PDV-BUS Protocol Chip MEE 3000

The chip from Valvo/Signetics handles all the protocol functions specified in the standard. It can

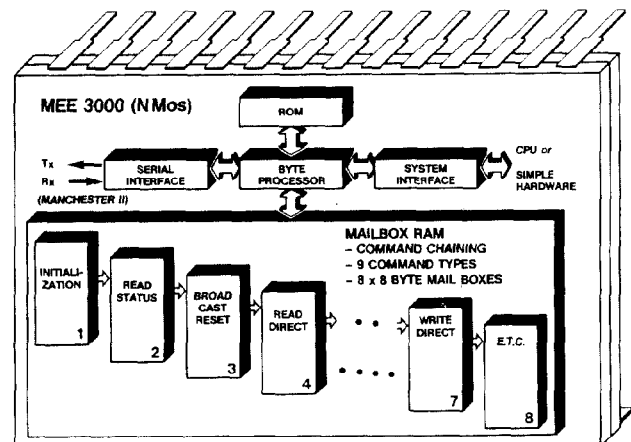


Fig. 2: Architecture of the Protocol Chip

operate with a microprocessor or standalone, in this case all the necessary functions for the initialization are performed during power up (e.g. reading the address of the node selected by dip switch). The on-chip processing unit simplifies software design for master and active slave stations by executing chained commands (up to 8) in an onchip mail box RAM. The chip has the necessary control lines for DMA transfers to the user's device, transmits and receives serial data alternatively in NRZ and in Manchester code.

#### Hardware Realization of the Stations

All the stations connected to the PDV-BUS use the same Medium Attachment Unit (MAU). This unit makes it possible:

- to isolate electrically the stations from the coaxial cable using transformers.
- to apply a relatively high signal amplitude on the cable using VMOS transistors (plus/minus 12 V at the MAU output).
- to drive max. 1000 m cable with max. number of 100 nodes (cable dependent).
- to support the Jabber Control function, which imposes the max. amount of time the transmitter can drive the cable. If the time of transmission is longer, the MAU will be switched off from the cable at the transformer.
- to switch off the station from the cable at the transformer during power failure.

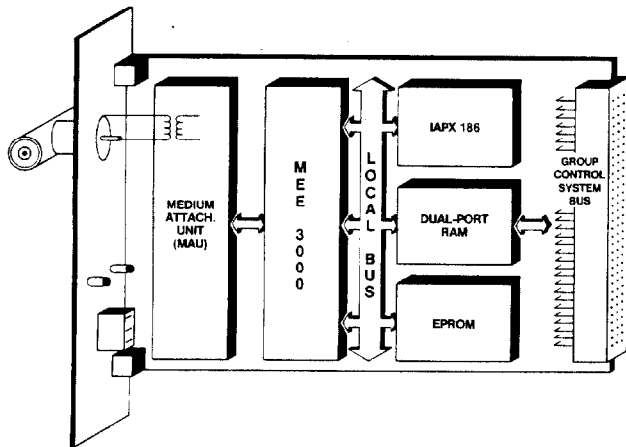


Fig. 3: Block Diagram of the Bus Driver's Hardware The Master

The master station is realized as a single Euro-card format (100x160 mm). It has 128 kbyte Dual-Port DRAM, maximum 128 kbyte EPROM memory and an interface to the SIEMENS SMP BUS (Siemens Microprocessor Bus). The CPU is an 8 MHz iAPX 186 processor. The Medium Attachment Unit and the PDV-BUS Protocol Chip are mounted on a piggy-back board.

#### The Slave Stations

An active slave station is realized by using the same Euro-card hardware as for a master station, but by specifying at the initialization of the VLSI chip, that the station is an active slave, rather than a master. The communications software running on an active slave is a subset of that running on the master. The slaves are supported with an EEPROM, used for the identification of a specific slave board and the characteristics of the connected equipment. There are two types of passive slave stations. One of the two uses a Dual-Port RAM interface. With such a passive

slave, it is possible to realize a close coupling of an intelligent system to the network. The second type of passive slave uses a looser coupling. As well as the Medium Attachment Unit and MEE 3000 components they have a simple or multiple 16 bit input/output register interface; thus they can be utilized as very simple slaves. During power up they perform a self initialization, reading an 8 bit station address from a selectable switch.

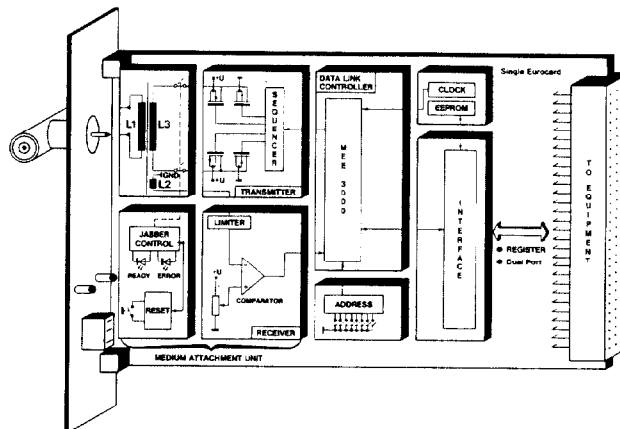


Fig. 4: Main Function Blocks of the Passive Slave (PDV Coupler) with Equipment Interface

#### Communications Software Package

The communications software is a general purpose package to implement services on the PDV-BUS up to a Remote Access Control level. It is designed to run on the PDV-BUS Controller Board of a master station and a subset of it runs on the board of an active slave. On the lowest level it has a driver part interfacing to the hardware, on the highest level a well defined user interface can communicate with the user program. Between the user interface and the hardware interface there are three main modules (Fig. 5). Concerning the functionality of the modules, these are:

- The Bus Access and Transfer of Mastership Control
- The Remote Access Control Module
- The Network Management Module.

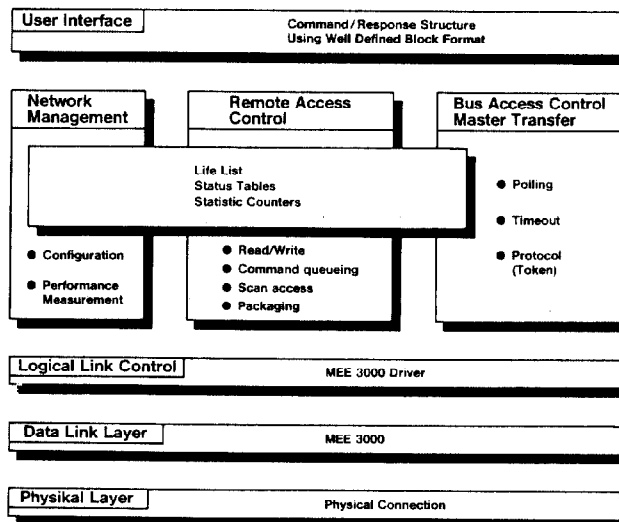


Fig. 5: Functions of the Bus Driver

## The User Interface

Through this interface a user can communicate with the communications package and vice versa. The protocol between the user program and the communications program has a command/response structure based on a well defined Request Block, which has the following form:

- Opcode: Defines the command
- Source Pointer: Parameter Block Pointer
- Destination Pointer: Parameter Block Pointer
- Token: To identify the command by the user
- Confirm: Status after the commands execution
- Data Bytes: Used for parameter transfer

## Bus Access and Transfer of Mastership Control

Normally the Bus Driver has exclusive access to the bus without any arbitration. The local console stations are polled by the master to give them the permission to execute one bus cycle. The transfer of mastership is implemented by the protocol. By monitoring the bus, a redundant master station can take over mastership after an appropriate time-out interval.

## The Remote Access Control Module

This module receives commands for execution and returns status after the commands execution to the user interface. If several commands are issued to the communications program it performs a command queueing. Some of the defined commands are:

- APPEND\_STATION            • INIT
  - REMOVE\_STATION          • SEND
  - READ\_STATISTIC TABLE   • RESET\_SLAVE
  - READ
  - SCAN (READ a predefined number of stations)
- etc.

## Network Management Functions

The network management is concerned with activities such as the configuration and reconfiguration of the network, reporting status information and performance analysis. The type of information handled by the module can be summarised as follows:

- Number of Active Stations
- Station Types
- Last Status of the Stations
- Total Number of Logical Send Messages
- Total Number of Logical Receive Messages
- Total Number of Physical Send Messages
- Total Number of Physical Receive Messages
- Count of Errors for each Station

## Conclusions

Process control systems using all protocol options of the PDV-BUS realized with discrete logic have been installed in severe industrial applications, proving the reliability of the standard. The available VLSI chip greatly simplifies the hardware and software design and together with the MAU positively effects the cost factor of a network. The low end communications system (field bus) in our laboratory uses a 400 kbit/sec data rate. This year the system will be tested in a harsh environment. Next year a CMOS VLSI chip with a 1 Mbit/sec data rate will be available. The physical layer has been successfully evaluated with 100 real bus couplers up to a 1 Mbit/sec data rate and a maximum cable length of 1 km. The component cost of a passive slave module is < \$ 70.

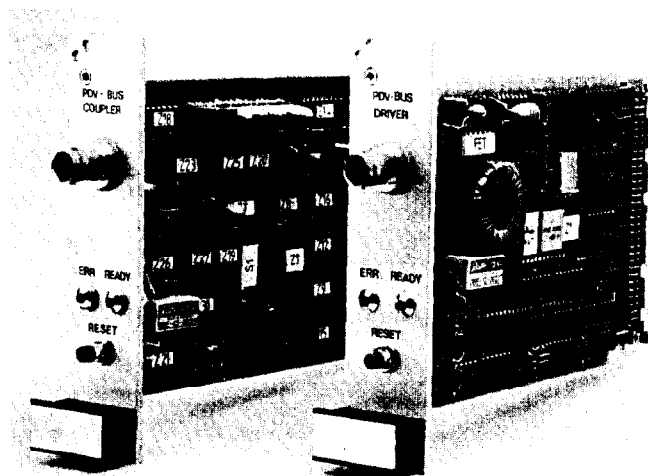


Fig. 6: Eurocard Boards of the Bus Driver and PDV Bus Coupler (Passive Slave)

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