Real time Ethernet VARAN Bus
The VARAN bus system meets all requirements of a modern industry network optimized for machine automation. It is based on IEEE 802.3 100TX standard Ethernet technology.

The protocol is implemented completely in the hardware, which reduces the load on the control CPU. All messages are acknowledged and repeated immediately in the event of an error. All data is therefore valid at the end of the bus cycle.

The VARAN bus makes a strong impression with its speed, openness, simple implementation and low costs, as well as its optimized real time performance and high reliability.

The entire bus is seen as a 4GB memory area, in which each client is assigned a defined memory space. Therefore, the control CPU can access each station with simple memory read and write instructions.

With the VARAN bus, the requirements for hard real time control are combined with those of automation and implemented using Ethernet technology. In order to take full advantage of the available networking, TCP/IP cross traffic is integrated. The technology is open and can be used by everyone. Collisions are avoided through the use of the Manager-Client principle. The VARAN bus can reach the highest speeds, shortest cycle times and minimum synchronicity jitter.

In addition, the VARAN bus offers the unique possibility of asynchronous direct access. Data packets are repeated within the cycle until a valid acknowledgment is received. Therefore, the validity of all data is guaranteed at the end of each cycle.

The VARAN bus can also, if required, transport standard Ethernet frames that are used for start-up and evaluation of clients.
The basic design of a VARAN implementation is identical for the manager and the client. The Ethernet physical layer is formed by the connectors, transmitters and the Ethernet PHY component. The PHY component provides auto-crossover so that standard CAT 5 cables (crossed or uncrossed) can be used. For the power supply, a 24V DC voltage can be integrated through the use of hybrid cables. Actuators and sensors are connected using a single connector, through which, the overall size and error sources can be reduced to a minimum. For the VARAN protocol implementation, an FPGA and a serial SPI Flash are required. Through the use of FPGAs application-specific add-ons can be integrated.

- **Guaranteed hard real time data transfer**
  Each instruction is immediately acknowledged by the receiver within the bus cycle.

- **Speed**
  High transfer rates, higher sample rate, higher control performance and increased data quality.

- **Automatic addressing**
  During the start-up phase, each network participant is assigned a virtual memory space, minimizing network planning and administration costs.

- **Hot plug capability**
  Participants can be added or removed during operation.

- **High reliability**
  In the event of an error, instructions are repeated immediately within the same bus cycle.

- **Open standard**
  The VARAN BUS USER ORGANIZATION (VNO) manages the open VARAN technology.

- **Direct access**
  In addition to isochronous and asynchronous data transfer, immediate high priority direct access to a client is also possible.

- **Protocol is implemented completely in the hardware**
  No additional load on the CPU.

- **Free choice of bus topology**
  Line, star or tree structures are possible.

- **Multi-manager capability**
  Networking of several autonomous systems.

- **Simple programming**
  For the bus manager, the bus system represents a large memory system. Each participant is assigned an area within this memory space, enabling the use of simple read/write instructions.

- **Simple implementation**
  even in small sensors and actuators.

- **Inexpensive**
  through the use of low cost standard components.

- **IP cross traffic**
  Standard TCP/IP cross traffic is also possible for the shortest cycle times.

- **Bus and power supply in a single cable**
  Simple signal and power connection through the VNO certified connectors and cables.

- **Simple maintenance and servicing**
  with comfortable service and diagnostic tools.
The VARAN Bus in Detail

One controls all: the VARAN manager administers the entire bus memory area, which can support up to 65,280 participants. Each participant is assigned its own linear address space of 65,536 bytes during the start-up phase.

Performance Data

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Isochronous access time</th>
<th>8 I/O’s = 1 Byte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus cycle time</td>
<td>&lt; 100 µs</td>
<td>2.18 µs</td>
<td>5.05 µs</td>
</tr>
<tr>
<td>Isochronous access time</td>
<td></td>
<td></td>
<td>1 Drive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>16 Bytes r/w</td>
</tr>
<tr>
<td>Asynchronous direct access</td>
<td>&lt; 25 µs</td>
<td>128 Bytes</td>
<td></td>
</tr>
<tr>
<td>Synchronous inaccuracy</td>
<td>&lt; 100 ns</td>
<td>Jitter</td>
<td></td>
</tr>
</tbody>
</table>

Portable to Gigabit Ethernet without protocol changes.

(Access time is only valid if the clients are connected directly to the manager)

The VARAN Manager

Each data transfer is initiated and centrally managed by the VARAN manager exclusively. All protocol-specific tasks of the VARAN manager are processed in the FPGA, which reduces the load on the control CPU.

The manager consists of several areas with various priority levels: Direct Access (DA), Asynchronous (ASYN), Isochronous (ISO). The VARAN manager according to the layer concept of the OSI model: Each data object in the application (Control Application) consists of a description field and a data field. The description field contains the address to be accessed, the number of bytes to be transferred, the identification for read and write as well as the number of retries allowed. Additionally, which action to take in the event of an error is also defined (exception or offline flag only). The data field contains the data objects.
The VARAN Bus Structure

Principally, any combination of line, star and tree structures is possible. A distributor, the so-called VARAN splitter, is used for building tree and star topologies. The VARAN splitter distributes the data packets to all output ports and shields the network from undesired access. The splitter function can be integrated in all clients. Using a superior VARAN manager, several VARAN systems can be cascaded into a complete synchronous network: A multi manager structure is thus generated, which enables several machines to be connected in synchronous real time without problems. The jitter is also under 100 ns.

Bus Cycle Distribution

At the start of each bus cycle, the manager sends a global SYNC instruction. The isochronous real-time objects are sent next, followed by the asynchronous objects and finally the data objects of the administration task. In the administration task, processes such as scanning for new stations or the transmission of Ethernet IP cross traffic are executed. The asynchronous direct access interrupts the running tasks for less than 25 µs to perform a client update during the bus cycle.

Communication timing: VARAN enables asynchronous direct access to bus stations at any time.
All Data is Valid at the End of a Cycle

When developing VARAN, special attention was given to the validity of data at the end of every cycle. The client acknowledges, immediately, every instruction received from the manager. If the client does not answer within the specified timeout period, or the answer is erroneous, the manager immediately repeats the instruction without incrementing the message counter until a valid response is received. The client thus recognizes the instruction as a repetition. This procedure guarantees that all data is valid at the end of the cycle. The constant testing of data validity, even with cycle times smaller than 100 µs, is only possible using small VARAN data frames (1-128 Bytes). The IEEE 1588-defined clock synchronization of the bus devices is not required for the VARAN bus.

Access Times in the µs Range

The update times are an essential aspect of real time Ethernet networks. When writing to 16 I/Os (instruction length of 2 Bytes), the VARAN bus has an update time of only 2 microseconds. Drives with 16-byte actual and set values, each can be processed with a single read/write instruction in 5 µs. These times increase by 1 µs per distributor node. To obtain short update and bus cycle times, a tree structure is therefore recommended.

Latency Time

For read and subsequent write access to a bus device, the latency period is maximal 1.5 bus cycles (including the processing of I/O data by the CPU).
The Ethernet cross traffic is controlled by the VARAN manager. Each client with a standard IP Ethernet port is detected and queried during the administration task for Ethernet frames that should be transmitted. Upcoming IP data is then transmitted to all IP nodes (IP tunneling).

All modules with a VARAN connection are assigned an electronic identification label containing the device-specific data:
- Vendor-ID
- Device-ID
- License number

Modules with an invalid identification label or an invalid license are deactivated.

The bus system is therefore protected against undesired participants.

It is also possible to add customer-specific files in the VARAN client. The module description, for example, can be saved in the client as a PDF and accessed via the VARAN service tool.

Safety protocols can also be transferred over the VARAN bus. The security level is defined by the applied safety protocol and the safety class of the participants.

In this case, the VARAN bus serves as the transmission medium only.

### VARAN Instruction Overview

- **Memory Read**: Reads data from the memory of a client. This instruction contains the start address and the number of bytes to be read. The client answers with the requested data.

- **Memory Write**: Writes data to a client memory space. The write command contains the start address and the data to be written. The client sends an acknowledgement.

  These two instructions can be combined into one Memory Read/Write instruction.

- **Global Write**: All bus participants are addressed simultaneously. This instruction is used, for example, for a global reset of bus devices or to transmit the SYNC command.

- **Foreign Package Request/Response**: Initiates the transportation of foreign data packets (TCP/IP, safety or other protocols) through the VARAN bus system.

### Connection Technology

Because real time Ethernet in the industrial automation branch demands high quality and robustness from connectors and cables, the VNO has worked intensively to perfect connection technology. For the IP20 area, the Harting RJ45 industrial is certified. This connector is tested for its industrial suitability. To meet the demands for low-cost machine wiring, solutions that require only one connector were developed for the connection of field bus devices in the IP67 world. For bus participants with 24V and a maximum current consumption of 2 A, the 8-pin M12 connector from Phoenix Contact is used. For high power devices (up to 10 A) and separate power supply requirements, a new 8+4 power/Ethernet connector was developed by Tyco Electronics. Corresponding hybrid cables are available for both variants.