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CAN Networks in Ship Automation Systems

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MCS-5 is a new, decentralized CAN-based automation system used mainly in ship automation. The system can be divided into two layers: monitoring and control, and process. This paper describes the function and the automation devices for each layer. The main points of the paper are the communication principles, protocol gateways and the use of PLCs within the system. The protocol layers and the communication services are explained. The paper also gives an overview of the PLC languages used.

The trend to decentralized automation systems significantly influenced the development of the new MTU **M**onitoring and **C**ontrol **S**ystem, MCS-5. The new quality of this automation system is data processing within the decentralized automation devices and data exchange between them over field bus systems.

The system architecture distinguishes between two layers:

- monitoring-and-control layer,
- process layer.

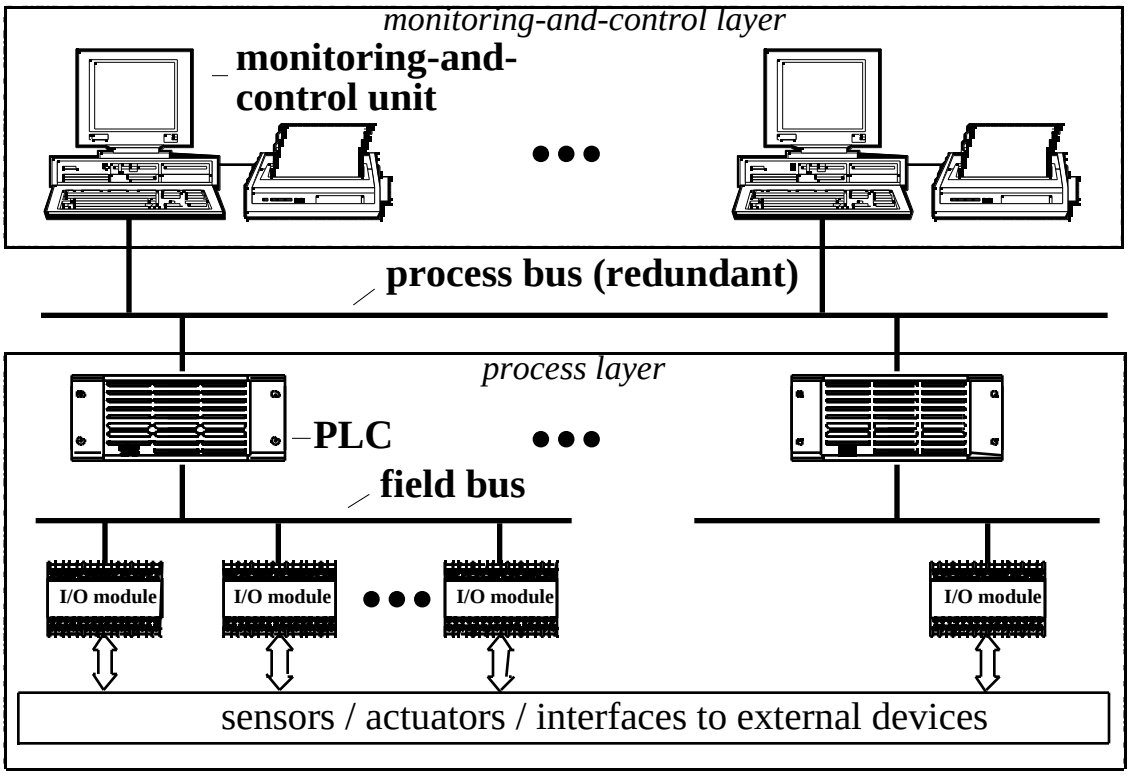

Figure 1: MCS-5 system design

The following presents a detailled description of each layer and how it operates.

Monitoring-and-Control-Layer

The **M**onitoring and **C**ontrol **U**nits (MCU) are the devices of this layer. Their main task is the visualization of data. The two main hardware parts are the industrial PC, and the CAN-bus communication card.
Data is exchanged between the **P**rogrammable **L**ogic **C**ontrols PLCs and MCUs on a redundant CAN bus. If an error occurs in one of the bus systems, the communication protocol switches to the available bus. Bus errors are handled by the decentralized system network management (NMT). This kind of decentralized network failure handling is new for redundant CAN bus systems. In comparison with CAL network management, for instance , a significantly higher system availability is assured.

Process Layer

Devices of the process layer are I/O modules for the data acquisition, and PLCs for data processing. Contrary to the common systems on the market, the PLC has no I/O channels of its own. Acquisition and pre-processing (standardization of measurement values) of process data are exclusive I/O module tasks. The treated process data are transferred by CAN field bus to the PLC. Data transfer from the I/O module to the PLC is cyclical. The cycle time for each measuring value can be configured. The advantage of this system design is its high modularity. Depending on the application, it is possible to choose the optimum I/O card configuration. The PLC has three CAN bus interfaces in its standard configuration. The I/O module consists of a **M**ain **P**rocessor **U**nit (MPU) and up to three additional I/O cards. The I/O card configuration can be freely chosen. Different sensor types, such as PT100, rpm measurement and binary outputs with checks for open wires are supported through a wide range of I/O cards. Each I/O module has one CAN bus interface in its standard configuration. It is possible to expand the I/O module with a second CAN bus interface. This expansion is optional to achieve redundant CAN field busses. The I/O module project data are not part of the firmware. The PLC downloads the project data automatically and recognizes by handshake whether the I/O module needs other project data. The corresponding download communication service is part of communication layer 7.

PLC Programming

PLC programming is done in **S**tructured **T**ext (ST) and in **F**unction **B**lock **D**iagrams (FBD) in accordance with the IEC standard IEC 1131-3. The PLC function block library was extended by application-specific and communication-specific function blocks. These communication function blocks have an easy-to-use user interface providing an interface to

the **A**pplication **L**ayer **I**nterface (ALI) of the communication protocol. The use of these function blocks does not require any communication protocol knowledge. For instance, to send a control command, the PLC programmer only selects the corresponding function block. The interface parameters of the function block are the control command value and the reference to the respective process variable. The process-variable reference is used by the communication protocol to initiate transmission of the control command. The communication-specific program components are part of the function block.

The PLC programmer is aided by a project support tool. This tool creates generally applicable, recurring PLC subprogramms. Examples are the handling of alarms and missing data. The automatically generated PLC source is Structured Text. The project-support-tool was developed together with the new automation system; support for all new products with this tool is planned. One of the following sections contains a more-detailed description of this software package.

Communication Protocol

A special communication protocol was specified and implemented for the new MCS-5 automation system. It conforms to the ISO/OSI layer model. The protocol stack contains only layers 1, 2 and 7. Parts of the other layers are constituent parts of layer 7. As an interface to the application programs "PLC Program" and "DDE Server" of the visualization, the communication protocol contains an **A**pplication **L**ayer **I**nterface (ALI). The communication object attributes are organized in an object catalog. The object catalog structure correspondends to the used data types. The supported data types are:

1. Signed Integer (analog , binary and control values)
2. Boolean (alarm and system failures)
3. Domain (project data).

Layer 7 distinguishes between Confirmed and Unconfirmed services. The implemented layer 7 contains the following services:

Confirmed Services

Service	Description
Read	Confirmed Read is used for activating / deactivating the cyclic transmission of measurement values from the process area
Write	Transmission of alarms, control commands and system error messages on the process bus
Domain Download	Download of the I/O module project data

Unconfirmed Services

Service	Description
Write	Transmission of cyclic measurement values from the PLCs to the MCUs
Local Write	Transmission of local system error messages
Set Time	Set the time for the entire system

Another essential part of the communication protocol is the decentralized network management, NMT which provides the following functions:

- network control of the process bus nodes with the help of a logical token ring,
- network control of the I/O modules through their life signals,
- handling of the CAN controller error messages,
- transmission of the current network status to the visualization.

Protocol Gateways

MCS-5 can integrate equipment of other companies with the help of protocol gateways. These automation devices are connected to a separate PLC and field bus. If the automation device has no CAN field bus interface, it can be connected via RS 422 or RS 232C interface to the PLC or to an I/O module. If the device is connected directly to the PLC, the **p**rotocol **d**ata **u**nits (pdu) of the external device are converted into MCS-5 CAN pdu's. The PLC communication protocol treates the external automation device as a normal I/O

module. The advantage of this concept is that only a small, device-related software portion must be integrated in the PLC; the other parts of the PLC firmware especially the communication protocol are not modified device specific.
To limit the variety of protocol gateways, the system offers a standard protocol for RS 422 / RS 232C interfaces.

Project Handling Enviroment

Manual project handling of a decentralized automation system requires a high effort and is subject to a high error rate. For this reason, a project handling tool was developed parallel to MCS-5. The main development aims were to automate the project process and decrease the error rate. The project handling tool is very important for creating the communication objects and the standard PLC programs. The tool generates the following project data:

- communication-project data (for instance, the object catalog),
- PLC standard programs and the PLC database,
- process visualization database.

Work to this subject continues.

EMC

All hardware components were developed to meet the demands of the classification societies for ship automation systems. The entire system, including the CAN-bus network, is EMC tested and fulfills all EMC requirements. The system is approved by seven classification societies.

Summary

The automation system offers solutions for various application fields. The reason for its flexibility is the modular system design and the hierarchical bus structure. The system is mainly used in the field of ship automation.