CAN as the backbone for pneumatic and electric Motion Control

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Motion control includes drives technologies and control systems with integrated software platforms. Currently, the drives are represented by pneumatic and electric technologies. A challenge for the suppliers of Motion Control solutions is to propose the common platform (hardware/software) which allows the easy use of pneumatic and electric drives.
Example of this platform could be hybrid valve terminal where the coexistence of these two technologies was possible thanks to:

- CAN bus used as the embedded backbone for communication with all elements of Motion Control system

- Common Data Profile for pneumatic and electric drives

1. Introduction

Hybrid and electric vehicles will change automotive world. Actually this change is dominated by hybrid technologies but nearly will be replaced by electric, fuel cell powered vehicles.
The same trend we can observe in automation world, in Motion Control Systems which combines pneumatic and electric technologies for drives and actuators.
Pneumatic and electric are not mutually exclusive. So, for Motion Control solutions, it is crucial to exploit all their strengths and to ensure that both technologies work seamlessly together on a common platform.
Example of this platform could be hybrid valve terminals, modular systems that combine pneumatic valves with electronic interfaces for sensing and for Motion Control of pneumatic and electric drives.

2. Evolution of Valve Terminals

To move a pneumatic actuator (e.g. simple cylinder) the chambers of the actuator must be alternatively switched to power pressure (compressed air) and to exhaust.
This switching is made by pneumatic valve on reaction to extern mechanic or electric command.

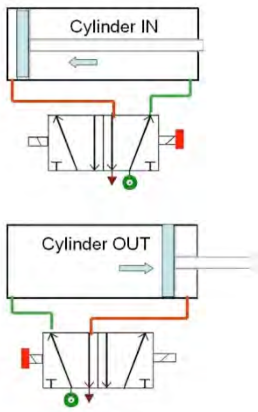

Figure1. Movements of pneumatic cylinder

The most used are solenoid valves with electric commands from controller.

Electrically, each solenoid needs a separate individual connection to controller output. And position sensors are connected to controller inputs.
Pneumatically, each valve needs its own pneumatic tubing and connectors to the actuator and compressed air supply.
So, this configuration is expensive and not reliable.

Phase 1
The first Valve Terminals were created by simple mounting of standard valves on the manifold with a common compressed air supply, simple local interface for sensors and solenoids connected individually to controller outputs.

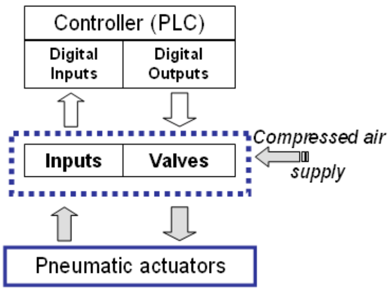

Figure2. First Valve Terminal

With fieldbuses, Valves Terminals were connected directly to inputs and outputs of the fieldbus nodes.

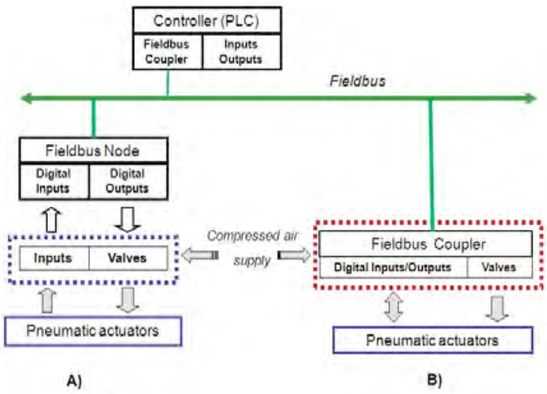

Figure3. Valve Terminals on fieldbus

The first main benefit for the users was drastically simplified pneumatic connection accomplished at the time of installation by mechanical personnel.
And because Valve Terminals can be mounted near actuators, shorten lengths of pneumatic tubing can be used: less matter, less work time, less engineering costs.

Phase 2
Next step were Valve Terminals with dedicated communication interface (fieldbus coupler) for direct connection onto network. As the result, electrical parallel wiring of solenoids and sensors was drastically simplified and replaced by one fieldbus connection easy to plug in.

Phase 3
Next step were modular Valve Terminals. Modular structure has made possible the integration of different (pneumatic and not pneumatic) functional modules and to configure Valve Terminal for the particular needs of the user's application.

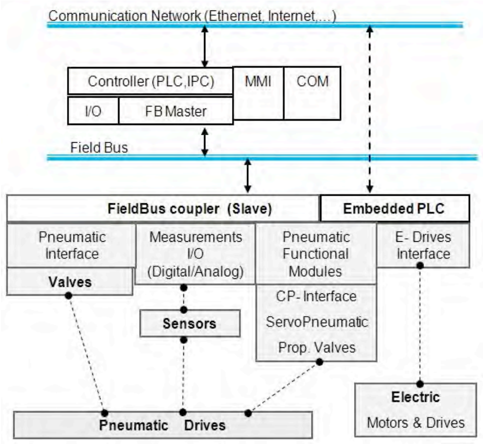

Figure4. Functionality of modern Valve Terminals

Finally, today, modern Valve Terminals have evolved into automation platforms with functional capabilities which include:

- Control of pneumatic actuators,
- Sensing (digital and analogue I/O's)
- Measurements (position, pressure, temperature),
- Proportional pressure regulation,
- Motion control with servo pneumatic and electric drives,
- Safety and diagnostic functions,
- Embedded PLC, …

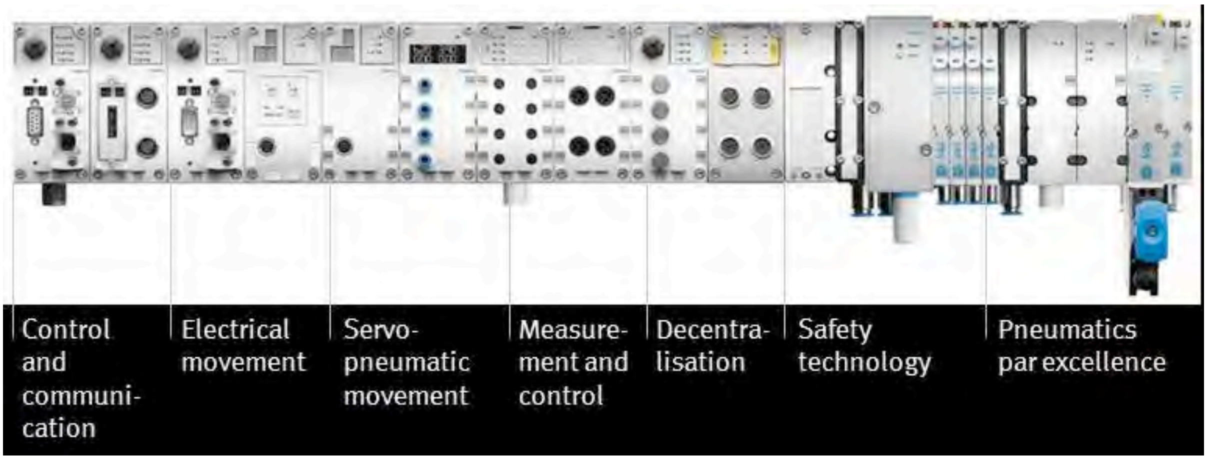

Figure5. Functionality supported by modern Valve Terminals

3. CAN network inside Valve Terminal

Integration of the CAN network in Valve Terminal is performed on three levels

- At Level 0 as internal bus that connects together all modules of therminal
- At Level -1 as communication network for decentralized (standard or specific) equipment
- At Level +1 as communication network with upper level equipment (CAN-enabled fieldbuses)

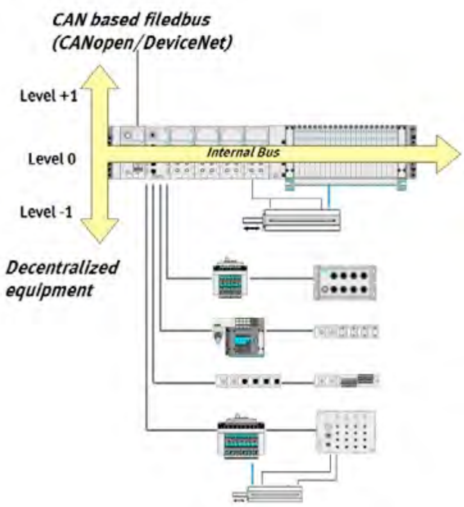

Figure6. Integration of CAN network inside Valve Terminal

3.1. Level 0: Internal communication bus

Internal CAN bus ties together all modules of Valve Terminal. CAN controller is integrated in ASIC (or FPGA) on every module. During startup (bootup) phase the controller of the main module executes identification of the configuration:

- Detection of each module **on right position**
- Detection of type of each module
- Comparison with nominal (stored) configuration

This approach makes simple an evolution and expansion of Valve Terminal, its commissioning, startup and diagnostic.

3.2.1. Level -1: Decentralized standard equipment

Modular extension of Valve terminal is limited. Depending of the needs, the number of digital I/O’s and solenoid valves can be expand with CAN-based network (e.g. CP-Interface Festo).
The base module, mounted on Valve Terminal, checks the configuration, parameterizes decentralized equipment and manages data exchanges and diagnostic messages.
This approach allows not only savings in cables and great flexibility for modular machines/robotic cells. Often, it provides new functionality, e.g. Hot Plug (tool change) mode.
Situation: each tool frame/carrier/module can be equipped with a different set of decentralized equipment. Every time where tool frame is changing during runtime, actual configuration is automatically recognized in short time (<10ms) without stopping the Valve Terminal and the main system.

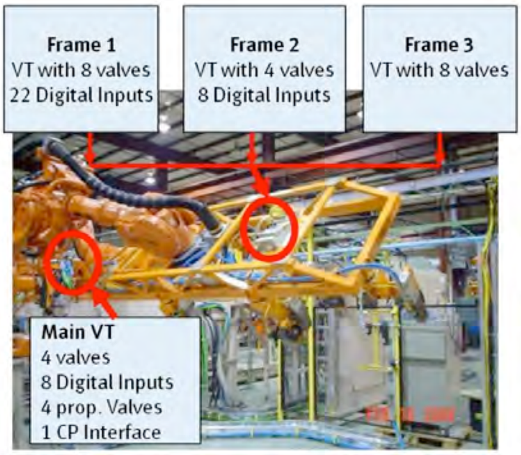

Figure7. Tool change mode (Hot Plug) for Valve Terminal

3.2.2 Level -1: Decentralized equipment for Motion Control modules

3.2.2.1 Servo pneumatic positioning

Motion control with servo pneumatic modules allows the positioning of up to eight pneumatic axes. Intelligent positioning modules combined with linear or rotary pneumatic actuators, with built-in encoders, can control force or position with an accuracy of ±0.2 mm. And an electronic end-position-cushioning ("smart" soft-stop) option can make cycle times up to 30% faster while ensuring shock and vibration-free travel between two hard stops.

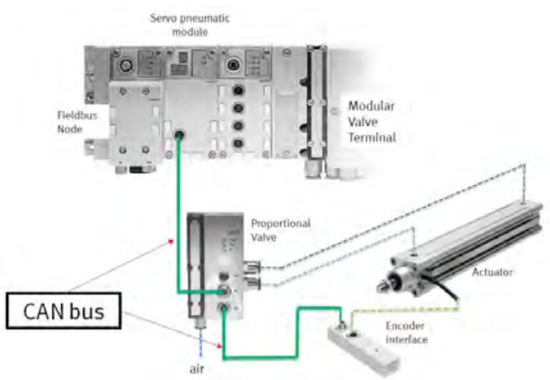

Figure8. Servo pneumatic positioning with Valve Terminal

The proportional valve, drive and displacement encoder are connected to form a closed−loop control circuit.
The proportional directional control valve is connected to Servo pneumatic module..
The sensor interface of displacement encoder is connected to valve.

These two connections are based on CAN bus with maximum permissible line length (total) < 30_m.
Exchanged data and commands allow realising of the following functions:

- Parameter storage (hardware configuration, controller settings, records with specified set point values (position, force, speed, etc.)
- Identification (static and dynamic) of the connected components
- Positioning control (position or force) by appropriate activation of the proportional directional valve.

The servo pneumatic module is integrated in a Valve Terminal as functional positioning module and is controlled by the main node via the internal bus using 8 bytes of module output and 8 bytes module input data (manufacturer specific data profile FHPP, see p.4)

3.2.2.2 Positioning with electric drives

For a Valve Terminal the functions of Motion-control with electric drives can be achieved in two ways:

- By integration of the simple gateway module (Motion Gateway) between upper level systems and the network of electric drives
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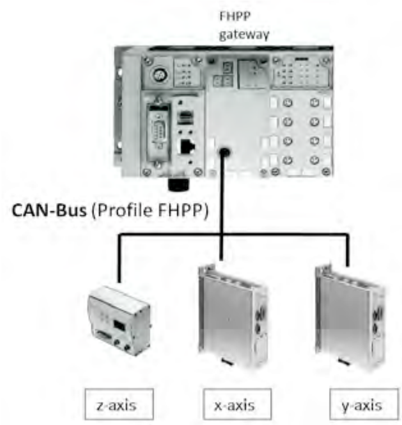

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Figure9. Positioning with electric drives: Motion gateway

- By integration of the intelligent (programmable) module ; the embedded Motion Controller

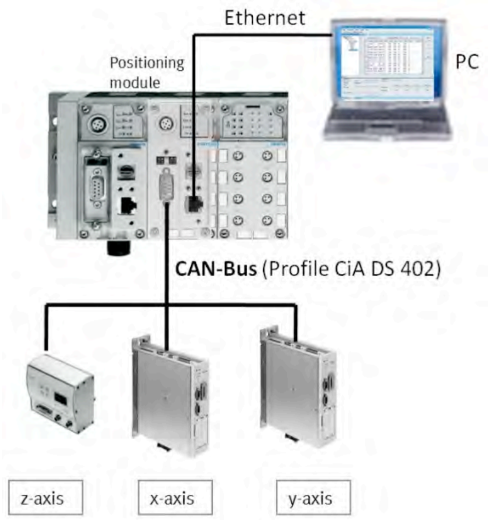

Figure 10. Positioning with electric drives: Embedded Motion Controller

The Motion Gateway is an interface for electric positioning and handling axes (up to 4). The axes are connected via CAN bus interface and use, in generally, the proprietary profiles for communication.

Programming of this kind of equipment is not required.

Motion control mode is Point-To-Point asynchronous mode: the axes are moving like single axes, no coordination.

Motion functions are controlled (over data profile FHPP) by higher order controller on main fieldbus or by PLC embedded directly in Valve Terminal,

The embedded multi-axis Motion Controller is an intelligent module in the Valve Terminal for controlling electrical drive units connected on CAN bus; e.g. two axis groups with up to four axes each.

The standard CiA DS402 profile is applied and coordinated, synchronous, PtP multi-axis movements can be achieved very easily.

Programming is not required for this kind of controller, but a software tool must be used to configure and parameterize the module, motor controllers and movements to be performed.

This kind of multi-axis interface can be controlled by a higher-order controller via main fieldbus or directly by the PLC embedded in Valve Terminal.

Communication with the module is performed over the manufacturer specific data profile FHPP and expanded for the multi-axis synchronous mode.

3.3. Level +1: Communication fieldbus

For modular Valve Terminals the communication task is performed by dedicated communication module.

Actually, the modern Valve Terminal is compatible with all common standards of industrial networks, including CAN-enabled fieldbuses as CANopen or DeviceNet.

E.g. for CANopen protocol, Valve terminals are compatible DS401 and DS 301 profiles.

And default settings (identifiers, OD and initial PDO mapping) correspond to predefined connection set for generic I/O modules.

A typical CANopen Object Dictionary for modular Valve Terminals is presented by

DSP-301 (v.4.01), **DSP-401** (v.2.0) conformity

Index (hex)	Objects
1000..1200	Communication Profile
1400..1403	Communication parameters for R_PDO 1..4
1600..1603	MAPPING parameters for R_PDO 1..4
1800..1803	Communication parameters for T_PDO 1..4
1A00..1A03	MAPPING parameters for T_PDO 1..4
2000..2110	System and module data (configuration)
2200..2210	System and module diagnostic data
2300..2310	Diagnostic memory (40 last errors)
2400..2421	System and module specific parameters
4000..4801	Function assignment module (Virtual modules)
5000..5FFF	Force tables (Inputs/Outputs)
6000, 6100	« Input Array » (U8/U16 inputs)
6200,6300	« Output Array » (U8/U16 outputs)
6206,6306	« Fault Mode Array » for the outputs
6207,6307	« Fault Mode Status » for the outputs
64xx	Analogue Inputs/Outputs (values, parameters)

Manufacturer Specific Profile

Table 1 Typical Object Dictionary for modular Valve terminal

4. Common data profile for pneumatic and electric motion

Each motion module on Valve Terminal is integrated as functional positioning module and is directly controlled via the internal bus. Communication with module is made via 8 I/O data bytes of the module.

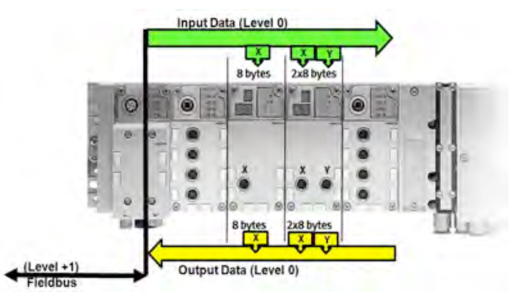

Figure11. Principles of communication with positioning modules on Valve Terminal

This approach allows the motion controllers to be uniformly controlled and programmed. And, easy implementation of all functions needed for motion control:

- Operating modes of controllers
- Data structures
- Control of motion sequences
- Parameters of controllers

4.1. FHPP frame

The content of the 8 I/O exchanged bytes is defined by manufacturer specific data profile FHPP: Festo Handling and Positioning Profile.
This profile was developed and optimised for handling and positioning functions realized by motion controllers for servo pneumatic and electric drives.

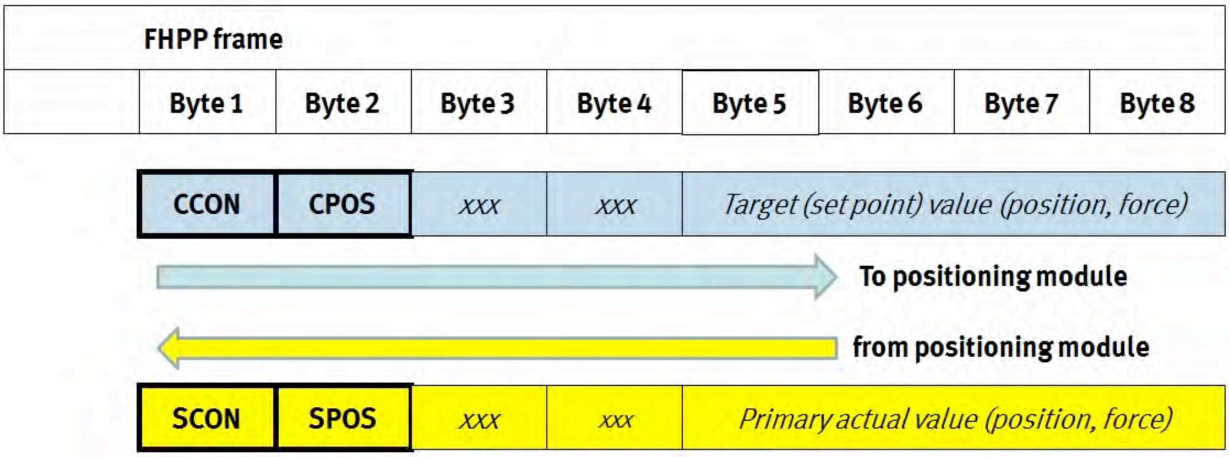

Figure12. Base of FHPP data profile (frame)

Bytes 1 and 2 are the same for every operating mode of motion task.
They contain control bytes (input frame) and status bytes (output frame).
Bytes 3 to 8 transmit further control and status bytes, as well as setpoint and actual values:

- Additional operating mode dependent data (e.g. speed, record number,..)
- Target position/force for direct mode in output data
- feedback of actual position/force in the input data

The content of these bytes (3 to 8) depends on the selected operating mode (direct mode, record select, positioning mode, force mode)

4.1.1. Control bytes

Control byte 1: CCON
The CCON is used for controlling the state of motion controller in all operating modes. Main commands are:

- Drive enable
- Stop of the movement
- Brake release
- Select operating mode

All commands performed by CCON are acknowledged by Status byte SCON

Byte of the Positioning Control CPOS
Control byte 2 (CPOS) is used to control the movement sequences as soon as the drive has been enabled:

- Start movement
- Start reference travel
- Jogging/ teaching
- Intermediate stop/ pause

All commands performed by CPOS are acknowledged by Status byte 2 SPOS.

4.1.2. Status bytes

Status byte 1: SCON
SCON gives feedback information on the controller status and acknowledges all commands sent by CCON.

- Drive enabled
- Error/ warning
- Load supply of drive
- Act. Operating mode

Status of the Positioning: SPOS
SPOS gives feedback information on the status of the positioning task launched by control byte CPOS.

- ACK for start
- Movement active
- MC Motion complete
- Pause active
- Following error
- ACK for teach in
- Still stand observation
- Axis referenced

5. Final remarks

The modern modular Valve Terminal forms a unique system that can combine pneumatics, servo-pneumatics, electric drives and I/O on the same platform.
Implementation of the CAN networks gives the possibility of plant-specific configuration and easy cost-effective expansion of the terminal. It creates flexibility and helps to protect investments in control equipment.

For motion control, an implementation of CAN allows to support, simultaneously and seamlessly, both motion technologies: pneumatic and electric.
And the use of the common specific data profile raises the simplicity and performance of motion control, especially in complex applications where these two technologies must coexist together.

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