A NEW PROFIBUS-DP SLAVE INTERFACE FOR CERN's VACUUM SECTOR GATE VALVE CONTROLLERS

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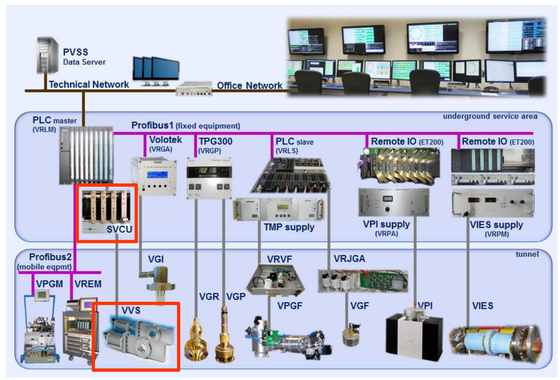
Abstract

The vacuum control systems of CERN's accelerators are based on PLCs, which communicate with controllers either with direct I/O, or via Profibus. In order to improve the communication efficiency of the vacuum sector valve controllers using direct I/O, a low cost Profibus DP slave interface card has been designed.

This paper describes the steps to design and test a Profibus DP slave interface that can match user's digital parallel bus. It presents the developed hardware and firmware, together with the corresponding assessment tests. It also flags the improvements of this new interface, in comparison with the previous system.

Sector Valve Control Unit (SVCU) Architecture



Introduction

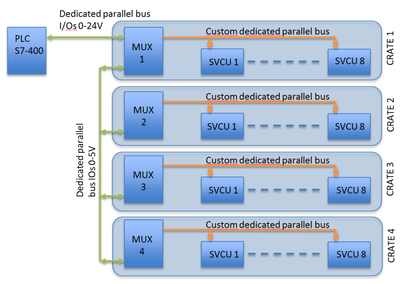
The vacuum chambers where circulates the beam of CERNs' accelerators must be maintained under Ultra High Vacuum (UHV) to minimize the beam interactions with residual gases, and allow the operation of specific systems.

The beam pipes are divided in several vacuum sectors that can be isolated by Vacuum Valves Gate Sector (VVGS), to avoid the propagation of leaks over a large volume. Upon the detection of a pressure rise above a predefined level, these valves will close in 1 to 3 s, depending on the model.

The vacuum control system is based on Siemens S7-400 PLCs. It uses Profibus to connect to the different vacuum controllers, except for the VVGS controller where direct I/O connections to the master PLC are used.

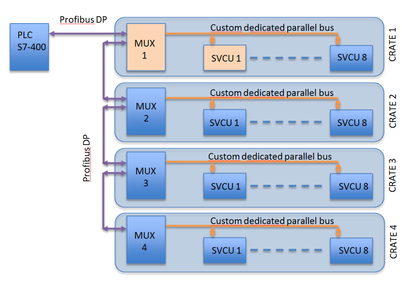
Each VVGS is controlled by its own controller (SVCU). PLC does not connect directly to the SVCU cards, but to a multiplexer (MUX) card first. The MUX card interfaces the PLC with multiple SVCU cards by translating the communication protocol.

Present architecture



- 26 wires dedicated parallel bus between PLC and MUX SVCU card
- Costly PLC I/O modules needed
- Up to 8x SVCU cards per crate; 4x crates connected together
- Up to 32x SVCU cards with one PLC connection
- PLC addresses each SVCU card individually
- A sequence of commands are needed to read or write each SVCU card
- Many PLC's CPU cycles; heavy/slow communication protocol

New architecture

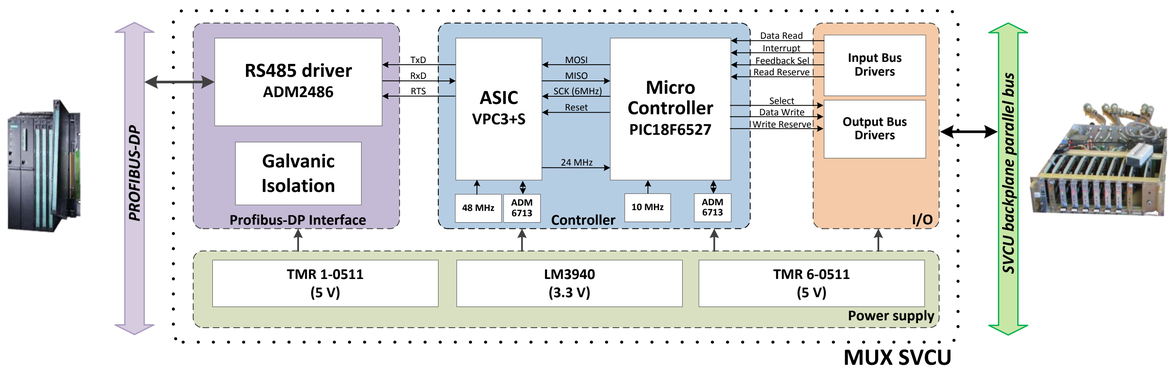


- Direct Profibus connection to the new MUX SVCU card
- PLC I/O modules not needed anymore
- Up to 8x SVCU cards per crate; 126x crates connected together
- Up to 1008x SVCU cards per Profibus network
- PLC addresses each crate individually
- Single Profibus cycle to read and write all 8x SVCU cards
- Unload PLC's CPU; faster communication protocol

New MUX SVCU Hardware

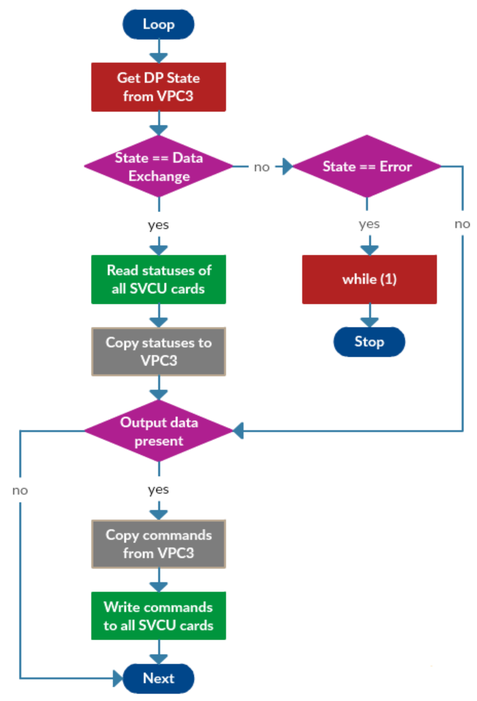
MUX SVCU card characteristics

- Eurocard 3U mechanical standard
- 4 layers PCB (top and bottom signals, internal power and ground planes)
- 8-bits PIC microcontroller (uC) from Microchip (PIC18F6527)
- Profibus DP slave controller ASIC form Profichip (VPC3+S)
- RS485 transceiver, all baud rate available from 9.6kBit/s to 12MBit/s
- 48MHz clock frequency for the VPC3+S ASIC
- 24MHz clock frequency (48MHz/2) for the uC
- 6MHz (24MHz/4) SPI clock frequency (Max. Freq that the ASIC can handle)
- Voltage supervisor for 5V and 3.3V power supplies and reset circuit
- Bus drivers for Input/Output connection to the backplane
- Profibus address selection by rotary switches on the front panel
- Access time for 8 SVCU cards < 1ms



New MUX SVCU Firmware

Core functionality flowchart



GSD file and protocol for PLC master

The General Station Description (GSD) file defines the Profibus slave (MUX SVCU) for the master (PLC). It is an electronic device data sheet or device data base file that identifies the Profibus device. All Profibus devices have their own GSD files.

For each SVCU
2 input bytes are needed:

SVCU1 Status page 1							
I 10.7	I 10.6	I 10.5	I 10.4	I 10.3	I 10.2	I 10.1	I 10.0
Pr. Sources not bypassed	All Loc. Pr. Sources OK	ITL from VVS+1 OK	ITL from VVS-1 OK	Temp. ITL OK	Press. ITL OK	Switch Open	Switch Closed

SVCU1 Status page 0							
I 11.7	I 11.6	I 11.5	I 11.4	I 11.3	I 11.2	I 11.1	I 11.0
Test pin not inserted	Ctrl key not active	Close enable OK	Beam Dump not Requested	Control Status OK	Remote	Switch Open	Switch Closed

1 output byte is needed:

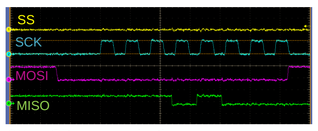
Write SVCU1							
Q 10.7	Q 10.6	Q 10.5	Q 10.4	Q 10.3	Q 10.2	Q 10.1	Q 10.0
Write Enable	Not used	Not used	Not used	Not used	Reset Interrupt	Open Valve	Close Valve

In one crate (one Profibus address) up to 8 SVCU cards can be present. In total, 16 input bytes and the 8 output bytes are necessary for one crate (MUX SVCU card). Then, the input and output data length defined in the GSD file must be as the following:

Module="16Byte=8WordIn 8ByteOut" 0x57,0x27

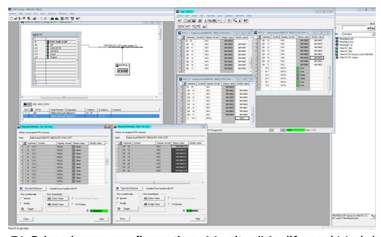
Test Bench

SPI communication test uC ⇔ VPC3
- All available frequencies from 375kHz to 6MHz
- Data written to the whole memory area of the VPC3, read back and checked
- Check VPC3's communication protocol implemented in uC
- Data logging with SPI protocol Analyzer
- Bus signals monitored with oscilloscope

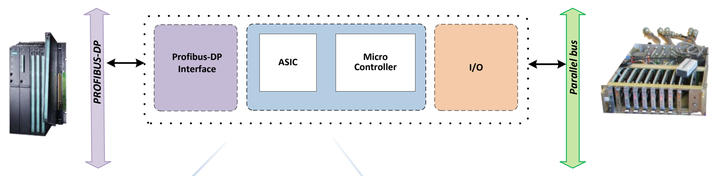


6MHz SPI communication

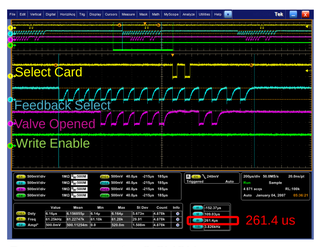
Communication test PLC ⇔ uC
- Data sent from the PLC to the uC and sent back to the PLC
- All baud rate from 9.6kBit/s to 12MBit/s
- Data checking with Siemens Step7 Software



PLC hardware configuration, Monitor/Modify and Variable Tables

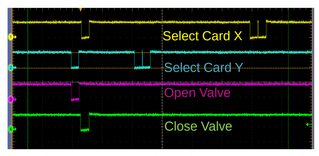


Benchmarks PLC ⇔ SVCU bus
- Program running in the PLC to test the complete read-write cycle time
- Different benchmarks to inspect the response times of the SVCU cards, measure cycle times and overall performance
- Bus signals monitored with oscilloscope



Read cycle time for 8 SVCU cards

Commands translation test PLC ⇔ SVCU bus
- Command sent from the PLC through Step7 Software
- Check that the MUX SVCU card handles correctly the protocol and generates correct bus signals
- Bus signals monitored with oscilloscope



Opening and closing the valves on two neighboring cards

Conclusion

Regarding the performance, the present version of the MUX SVCU card needs 30 to 50ms to read or write one single status page or command into one single valve controller. Now, with the new version of the MUX SVCU card, the cycle period is less than 1ms. In addition, in the new system, both status pages of all sector valve controllers are read, and every of them can be written within a single cycle. In the worst case, when all valve controllers need to be read and written, it will take only 1ms instead of 880ms. This faster sampling period is important particularly for interlocks and beam dump request data logging. Furthermore, this new design allows the connection of all SVCU crates directly to the Profibus network, like the major part of the vacuum controllers used at CERN. No additional I/O modules need to be connected to the master PLC.

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