

UNIFORM MOTION CONTROL SOLUTION FOR VARIETY OF MOTION APPLICATIONS

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Abstract

Control solutions for motion applications require high degree of flexibility regarding the use and connectivity. Being fairly simple or highly complex, micro- or millimeter precision, one or multiple axis... the system designer has to tackle specific interfacing issues. One platform should fit different applications and provide cost effective solutions. Flexible software platform is required on one side to satisfy control system (CS) application requirements. On the other side variety of hardware (HW)—controlled by motion controller, i.e. power stages, position feedback—also requires some degree of connection flexibility. Paper presents a design of a motion control platform that offers flexible interfacing both to CS and HW, elegant extendibility options for selection of feedback protocols, low-level direct access for engineering control and enables large distances between controller and motors.

INTRODUCTION

Every accelerator facility features several hundreds motion mechanical systems that need to be precisely moved in/out or along the path of the beam. These are ranging from straightforward single-axis devices (e.g. slits), extending over more complex devices requiring parallel movement (e.g. septum, undulators) to fairly complex multi-axis systems like hexapods.

Different motors must be utilized to suite the motion dynamics and torque requirements; different types, sizes and phases (e.g. servos, steppers, brushless, etc.). Besides just controlling motors, special care must be taken for protecting the mechanics and system; this requires the use of limit switches, inclinometers, interlock signals, etc. To have trustworthy control over the position of the mechanics, additional position read-back systems are employed; either incremental or absolute or combination of both. Motion control system must be capable of reading them.

Last but not least, the motion control system should be flexible enough to provide flexible control system integration and for debugging-purposes independent standalone operation.

To lower the development and commissioning effort for a newly constructed insertion device, a scalable and robust motion control platform addressing all previous aspects is required.

MOTION CONTROL REQUIREMENTS

When looking for a motion control solution one should have in mind all the following aspects:

- Signals' electrical and functional compatibility, which include signals for motor power drivers, motors itself, brakes if available, limit switches, position feedback devices, etc.
- Control system (CS) and software (SW) compatibility; various CS flavours exist and solution chosen must be compatible with your CS. Furthermore, SW flexibility is also important as it influences ease of CS integration and small, but important, features like basic engineering tests.
- Motion control aspects; motion control algorithms, multi-coordinate system calculations, multi-axes synchronous movement, incremental/absolute feedback control, soft and hard safety limits, acceleration and deceleration, motion tuning, movement interpolation, PID controls, inverse/forward kinematics calculation for robotics applications, etc).
- Platform aspects: mechanical dimensions, robustness, maintainability, expandability, total cost of ownership, etc.

In the following text we present a solution designed to address all the above aspects.

SYSTEM OVERVIEW

We designed a solution that consists of three basic subsystems:

- A single board computer (SBC), providing SW support. This is a PC/104 (PC/104+) x86 compatible platform, providing the functionality comparable to PC systems. Linux, VxWorks and UNIX flavoured operation systems can be used.
- Versatile Delta Tau's PMAC motion controller [1], presented in further text.
- HW interface electronics, providing functional and electrical-level configurability, presented in further text.

Figure 1 presents an overview of a motion control solution, focusing only on high-level aspects of the solutions.

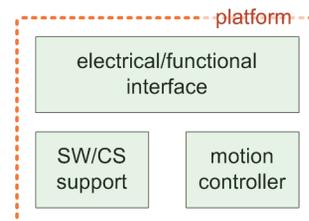


Figure 1: Motion control platform overview.

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Integration into the Control System

The support for the control system integration is provided using microIOC platform [2]. This platform is based around SBC, especially designed for use in stressed and rough environments. It provides the complete functionality of the personal computer, but sized down to the quarter of letter-paper size.

Normally, microIOC runs Linux operating system, Debian distribution, which is booted from the compact flash card. If required, other operating systems are supported. This represents a host platform for a system-driver, providing communication to PMAC and position feedback system. On top of this system a CS support is made, providing a CS server for remote control. Usually, in parallel to device manager a low-level command line application is made that provides direct low-level control. This is useful for testing and debugging purposes and can be employed by either connecting to microIOC through SSH connection or by simply attaching VGA monitor and keyboard.

SBC is equipped with two Ethernet connections; one is used for CS connection and the other is used for configuring and controlling PMAC.

Motion Controller

The core of the motion control solution is based on the DSP-based Delta Tau's PMAC [1], which runs motion control SW independent of SBC SW, but is controlled from it. PMAC is highly versatile motion controller providing synchronous control of up to 8 axes. Each axis can have defined its acceleration and deceleration curve, maximum speed, limit switches, etc. It can handle reverse kinematics motion, multiple coordinate transformations and much more. PMAC handles motion control by executing motion control programs that are downloaded and permanently stored in its memory. Configuration download and runtime control is done over Ethernet (from SBC). PMAC is responsible solely for executing motion programs, requested by SBC. CS integration is handled by SBC, thus providing failure-safe standalone motion control.

HW Interface

The third generation motion-controller development has taken connectivity flexibility a whole step further. From the previous projects we learned that the majority of systems required some more or less minor adjustments, which prevented straightforward (re)configuration for a particular application. To cope with this, we introduced two-level re-configurability.

First, all PMAC signals are passed through a CPLD-based interface board (XPLA3 family, [3]), which permits all kinds of signal cross-connectivity from the outside world towards the PMAC (e.g. supervising signals and taking certain actions, gating signals under certain conditions, negating certain signals to make them compatible with the power stage used, etc.) and even provides additional signals per axis, which are not part of

the motion controller itself, but are still essential for the entire system (e.g. brake signal if it is not supported by the motor driver itself, interlock input per axis, axis moving signals, etc.). Control of additional signals is implemented by means of PMAC memory mapped CPLD registers that are easily accessed through the PMAC via SW.

Second, the interface board is modularly extended with signal conditioning output (SCO) modules, which enable HW-level adaptation, directly suited for the externally-located power drivers and the rest of the system. All of the signals going out of the controller are optically isolated and can be defined as active (i.e. voltage sourcing) or passive outputs (i.e. providing short/open circuit). In the same manner all of the inputs can be defined as passive (i.e. switches providing only short/open circuit) or active (switches providing voltage). The voltage level for all the input and output signals can be easily defined. The entire system is also designed in such a way that very large distances (~250m) are supported between the controller part and the power drivers.

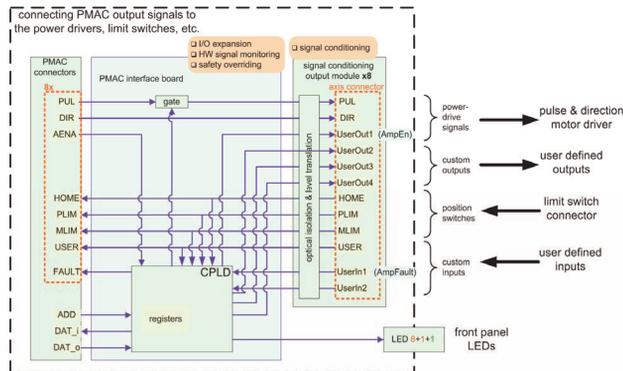


Figure 2: Functional and electrical-level configurability.

Position Feedback

A special emphasis was made with regards to the feedback system support. Motion control solutions exist with wide variety of position feedback solutions; sliding or rotary potentiometers (for radiation critical applications), basic quadrature incremental positioning, incremental or absolute digital EnDat positioning, serial digital SSI readback, etc... microIOC platform solution is flexible enough to allow elegant solutions for variety of feedback types.

For example, for the GSI [4] we provided a combined solution for potentiometer and SSI encoder position feedback. There was additional constraint to have the controller part (i.e. microIOC-M-Box) separated from the power drive case (PDC) for 250 m. We decided to for a precision remote voltage reference circuit built into PDC (close to motors and feedback potentiometers) and remote 8-channel 16-bit analogue to digital RS485 serial converter [5]. The analogue feedback values are this way digitized and available over RS485 serial link to microIOC, thus making it robust for the distance and noise. SSI encoders were supported in a similar manner;

we developed a 4-channel ARM based SSI to RS485 serial converter, thus making this feedback path seen very similar to the potentiometer based. As a precaution for noisy environment, microIOC provides optically isolated RS-485 ports.

For APS [6] we developed a solution that required EnDat feedback system. For this we used PC/104 based extension card providing EnDat interface. This way, a position feedback was directly available through the SBC and was appropriately passed to PMAC motion controller for position corrections.

Of course there is also a plethora of feedback protocol, like for example quadrature incremental, which are directly supported by the PMAC motion controller. With this kind of position protocols, only appropriate electrical-level has to be provided (normally we provide input channel protection and power supply for the encoder).

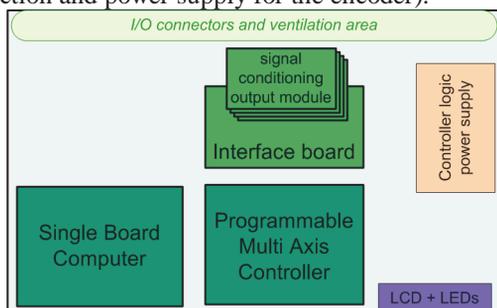


Figure 3: 3rd generation microIOC-M-Box.

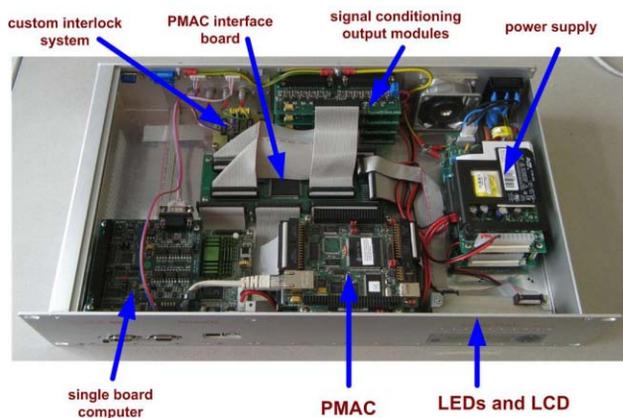


Figure 4: Inside of the microIOC-M-Box.

Power Drive Case, PDC

PDC is a complementary solution to microIOC-M-Box and as the name suggests, it integrates power drives for direct connection of the motors. It is designed to be connected directly to microIOC-M-Box. Depending on the application requirements it can be either mounted locally to microIOC or separated for several hundred meters. Additionally, encoder conversion systems can be also integrated within it.

All the communication between microIOC and PDC is done using either optically isolated RS-485 line or

optically isolated 24V low-power signal (driving optocoupler inputs).



Figure 5: Inside of the PDC.

SUMMARY

This paper presented an overview of the motion control platform solution. We exposed important issues that have to be addressed when a flexible platform needs to be built. A stress was put on a motion controller that can be easily customized for different applications.

The main benefits of our solution, which simultaneously controls 8 axes, are:

- a rugged 3U-high single case, with integrated power supplies that requires no external cabling,
- a Turbo PMAC2 based motion controller, providing support for a large number of motor types,
- a flexible configurable platform, offering rich extensibility options for new types of motors, encoder feedbacks, switches and additional IO signals,
- use of standard COTS (commercial of the shelf) components, carefully assembled and interfaced through our proven and well-tested CPLD programmable interface board and signal condition units,
- a dedicated CPLD programmable PMAC-motor interface board, providing hardware reconfiguration for IO connections and an additional hardware protection layer (e.g. for interlocks),

For the future we are thinking of re-designing the presented solution to provide a complete turn-key solution within a single case.

REFERENCES

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- [2] microIOC homepage: www.microioc.com
- [3] Xilinx homepage: www.xilinx.com
- [4] Gesellschaft für Schwerionenforschung: www.gsi.de
- [5] ICP DAS homepage: www.icpdas.com
- [6] Advanced Photon Source: www.aps.anl.gov