

Rapid Controller Prototyping Platform for Precision Applications

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Abstract

This paper presents a rapid controller prototyping platform for precision applications. It consists of a Compact-PCI based system running Linux RTAI, a hard real-time extension of the Linux operating system. Executable code for the platform can be automatically generated from common Control Design tools.

The platform combines in a unique way high performance for the control of precision applications, the flexibility typical of rapid control prototyping systems and a moderate cost. Thus, it can be used not only during the development of a precision system but also in end-user applications.

A small demonstration setup presents the performance of the platform: Positioning accuracy of 15nm is achieved in less than 30ms after a movement of 1mm.

1 Introduction

The development of mechatronic systems benefits from early tests which allow validating the system design and the control strategies. Such early tests can be performed using a rapid controller prototyping system which is able to implement a controller well before the final control hardware is available. In fact, the design of the final hardware may be influenced by the insight gained with such early tests.

In general, the use of rapid controller prototyping systems during the development of *precision* mechatronic systems is not trivial, because suitable measurement and actuation interfaces are usually not available. Then, time and effort consuming setups are often necessary in order to test a precision mechatronic system at an early stage. Following that, the final control system still has to be developed. The result is

often a control system which is tailored to the specific application and hardly reusable for future applications.

The present work presents a novel rapid controller prototyping platform for precision applications. The platform is easily configurable: Functional and performance tests of a precision mechatronic system can be set up and run with minimal effort.

Moreover, the low cost of the platform makes it interesting even for low-volume products, in particular if adaptations to customer requirements are necessary. Thus, the use of the platform speeds up the development phase, reduces the cost of the final system (the same hardware can be reused for many applications without having to repeatedly adapt or re-developed control hardware and software) and promotes a better capitalization of the know-how gained in previous development activities.

2 The Hardware

The platform is composed of a commercial Compact-PCI rack with a power supply unit and an X86 processor based computing board. Two specialized boards were developed for the platform: A sinusoidal signal interpolation board and a driver board for voice-coil motors.

The platform also supports all boards listed by the comedi project (www.comedi.org). Other Compact-PCI boards may also be used but the corresponding drivers have first to be written.

2.1 The Sincos interpolation board

The 3 channel sinusoidal encoder interpolation board processes 1V_{pp} sinusoidal signals. It is built on a commercially available IC which is able to sample the 3 inputs at a frequency of 500kHz and to resolve 13 bits within a signal period.

A new board is being developed, which automatically calibrates the input signals for an even better accuracy of the measurements [3].

2.2 The driver board

The 3 channel driver board delivers currents up to 3.5 A per channel with 16 bits resolution. The board can be configured to deliver less current in order to improve the obtainable current resolution.

Multiple boards can be used together, making it possible to control up to 16 axis. The platform with one Sincos board and one driver board used to control a 1-degree-of-freedom flexure mechanism is shown in Figure 1.

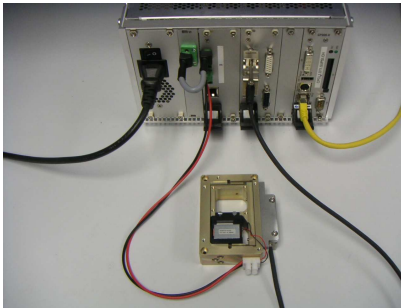


Figure 1: Rapid controller prototyping platform with a 1DOF structure

The Software

The present work exploits the results of the RTAI project ([1], [2], or www.rtai.org), which offers a real-time extension of the Linux operating system and interfaces with various CACSD tools (Matlab/Simulink, Scilab/Scicos or EicasLab are supported).

A sequence of activities can be performed within the same environment. A graphical model can be prepared to feed the process with excitation signals and to retrieve data for the identification. After the identification, the controller can be designed and the resulting closed-loop simulated. Finally, the controller code can be automatically generated and executed. The real-time application can send data to a remote computer, where the data can be displayed, stored and later analyzed.

In practice it is advantageous to install the control design environment on a separated, standard PC. This may even run a different operating system like Windows. Then, no development environment or graphical support is needed on the real-time platform and the requirements on the control hardware (RAM, computing power) are reduced, thus minimizing the cost of the platform hardware.

4 A sample application

The sample application considered here consists of the 1DOF flexure mechanism shown in Figure 1. It has an optical sensor with a 4 micrometer grating period and 8 bits resolution per signal period length. The achieved positioning accuracy is better

than 15 nm (see Figure 2). The 18 Hz open-loop bandwidth of the mechanical system has been raised to 80 Hz in the closed-loop. The 5 kHz sampling frequency used in the example would accommodate the control of 6 axes simultaneously.

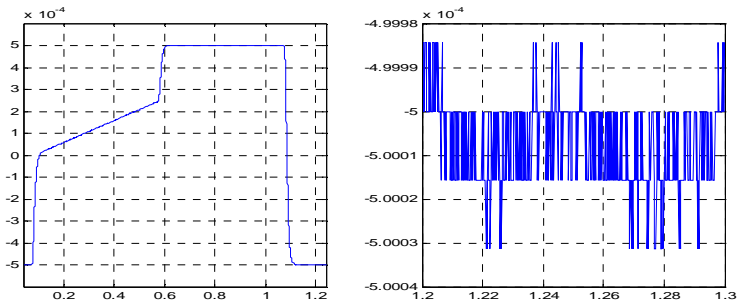


Figure 2: Tracking of a reference trajectory with a 1 mm step at time 1.1 s (left plot). Position measurement for constant reference (right plot), displacement in meters.

5 Conclusions

The platform presented in the paper combines great flexibility, high performance with moderate cost. Then, precision applications can be implemented rapidly and, at least for small quantities, brought to the market without any engineering phase.

Acknowledgments:

The author is indebted to many colleagues who have contributed to the development of the platform, in particular R. Bucher (LinuxRTAI and the integration of the CACSD tools), G.C. Dozio (board design), R. Bernasconi (firmware), F. Antonioli (software driver) and I. Furlan (tests).

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