High-end, low-cost motion control

In addition to its core business education, Fontys University of Applied Sciences, based in the Southern Netherlands, also conducts research in a number of specific subject units. One of these research groups – Mechatronics – is headed by lector Henk Kiela in Eindhoven, the Netherlands. Mechatronics focuses its research on high-end applications. One of its projects - "Low Cost Motion" - is about developing a high-end, low-cost motion controller.

• *Mark Stappers* •

The "Low Cost Motion" project ran from 2008 to spring 2010. Funded by RAAK, the Ministry of Education's Regional Attention and Action for Knowledge circulation scheme, the project was a spin-off of Paul Verstegen's Ph.D. research on a new concept for a pick & place machine. Despite using advanced techniques, not all solutions turned out to be easy to implement. For example, the controller used did not meet signal processing speed requirements. As a possible solution to these problems, the implementation of certain tasks by a Field Programmable Gate Array (FPGA) was considered. An FPGA makes it possible to describe hardware. Because the description is on the hardware level, it is possible to carry out processes in parallel. By doing calculations simultaneously, the FPGA information output can be many times higher than for microprocessors.

FPGA-based controller

A survey of high-tech companies in the Eindhoven region revealed that they had encountered similar problems and had decided to build their own motion controller. Their choice for a custom-made board was based on technical and/or financial grounds. The question arose whether Fontys could find a solution for these common problems by combining the knowledge of various companies (such as Assembléon, Bosch Rexroth, CCM and Philips Healthcare) into one project to develop a high-end, low-cost motion controller.

It was decided to make the design of the controller fully FPGA-based, which required custom-built hardware for driving motors and collecting information from sensors, as well as custom-built software; see Figure 1 for a general overview. In the project, several types of boards were

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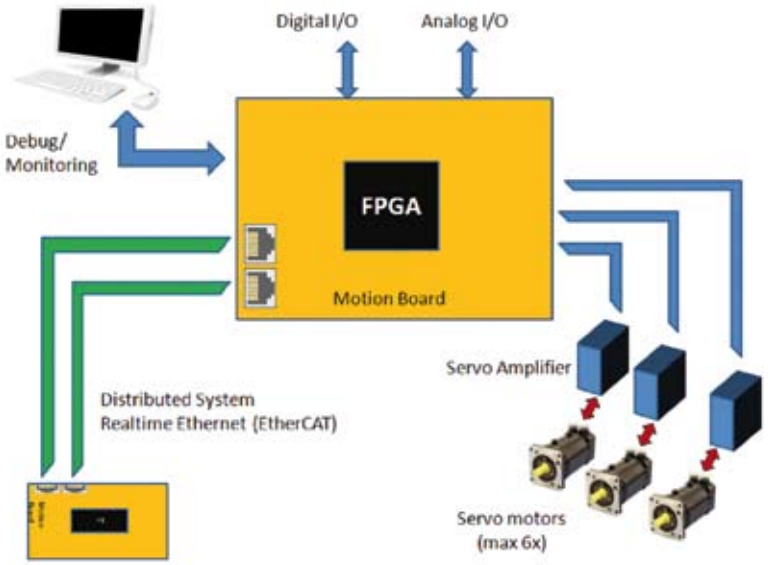

Figure 1. Overview of the FPGA-based motion controller design.

developed for motion control. Exploring the possibilities of the FPGA, a board was initially developed that could control a single axle. The board was able to handle signals at TTL level (S0/S90) or analog signals (sin/cos), and the output was an analog signal between -10V and +10V.

Open source

FPGA programming is done at hardware level, which means that logical AND and OR ports are connected in order to generate functions. These functions can be stored as a “black box”, so the user should be able to use these blocks without knowing the underlying code. In this respect, it is similar to an IC: the function can be used without knowledge of the underlying electronics. Alternatively, functions can be made “open source”. The main advantage of this is the possibility of seeing the underlying code. Most of the code in this project is open source and available to the participants. By combining different functions from a library, a dedicated motion controller for a particular device can be compiled; see Figure 2.

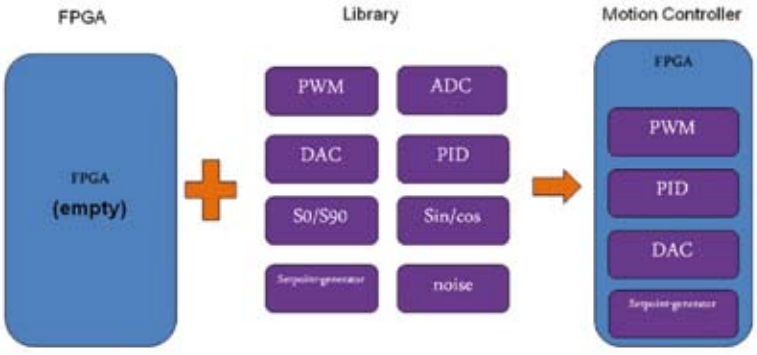

Figure 2. FPGA-based programming of a motion controller.

Configuration

Examples of functions developed include a control loop that was designed to work at an update frequency of 50 kHz. Another development involved an adaptive setpoint generator capable of positioning with an accuracy of 1 µm, with a 2 m/s maximum velocity and 35 m/s^2 maximum acceleration.
The general idea was that a non-technical person should be able to handle the motion controller. Therefore, software was developed for a PC-based user interface that allows easy configuration of the controller; see Figure 3. The serial communication between the PC and the motion controller allowed a data rate of 921,600 kB/s. The resulting controller was used to control an Assembléon pick & place machine. This proved that it was possible to build a high-end, fully FPGA-based motion controller.

Figure 3. Snapshot of the user interface.

Multiple axles

The next step was to design a board for the control of multiple axles. Starting from a single-axle control board, the number of axles was expanded to six. To be able to implement more algorithms, an FPGA with multiple gates was selected. To showcase the latest techniques for communication between devices, besides the standard RS232 connector, the board was equipped with a realtime EtherCAT fieldbus; see Figure 4.

EtherCAT is an ethernet-based full-duplex protocol. The primary advantage of the EtherCAT protocol is that all information runs through a standard ethernet cable.

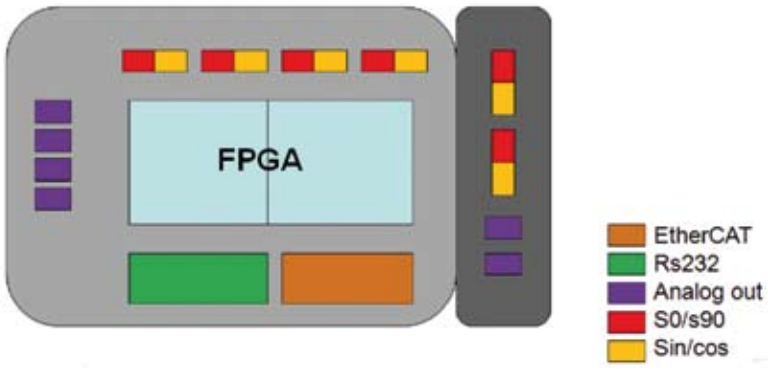

Figure 4. Schematic of the board with its I/O ports.

Moreover, it provides space for existing network protocols such as email, http, etc. To illustrate how fast the EtherCAT protocol is, 1000 I/O ports can be updated in 30 µs. In addition, this protocol's high level of flexibility means it can work with all types of network topologies.

Conclusion

The 6-axle motion controller is now being tested. As a preliminary conclusion, it may be stated that FPGA-implementation allows the development of a high-end motion controller at a reasonable cost; see Figure 5. Applications may be found in pick & place machines, robotics and the automotive sector. The project has encouraged several participating companies to integrate EtherCAT technology into their products.
At Fontys, the research results will be incorporated in both the education programme and new research projects on topics such as remote robotics.

Information

www.fontys.nl/mechatronica

Figure 5. The final result: a high-end, low-cost motion control board.