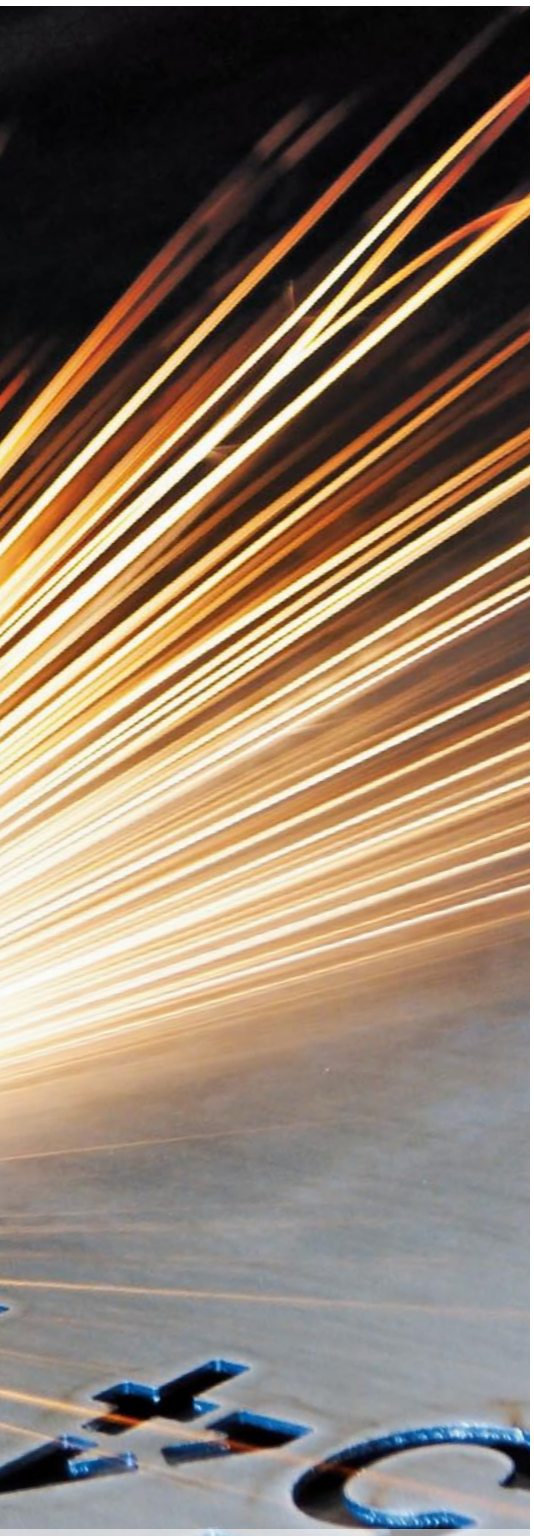
Systematic Drive Safety

Integration testing with a modular FPGA platform for SIL-3 drives technology



E-Darc is a new FPGA-based drive controller being developed by control system manufacturer Ferrocontrol. With the aid of dSPACE hardware and software, Ferrocontrol is testing the safety and reliability of individual models to ensure that they comply with the strictest quality guidelines.

At Ferrocontrol, we develop, manufacture and distribute automation components and complete automation solutions in the field of drives technology (hardware and software) for the manufacturers of processing machines and also for end users. Our goal is to develop a controller that is easy to configure and maintain, even for complex systems, so that highly automated production processes can be designed efficiently and economically. To meet these requirements, we developed the FPGA-based drive controller E-Darc.

E-Darc, the FPGA-Based Drive System

E-Darc is especially suitable for multi-axle applications in drives and automation technology, such as in timber processing or window-frame machining centers, and for CNC processing centers in general. Axle modules with output currents from 2 to 32 A and supply modules in a range of 5 to 25 kW cover a wide range of user requirements. The number of controllers that are addressed depends solely on the available supply power: E-Darc itself has

Figure 1: The E-Darc drive controller consists of several modules for controlling several axles together.

no limits (figure 1). We designed the system so that the entire drive control is on one FPGA in parallel, "caste in VHDL" so to speak. This quasi-analog control provides the greatest possible dynamics, even for position and rotational speed control. Oversampling procedures are used for capturing position and current measurements to improve the quality of control without producing additional latencies within the control loop. Actual value filters are therefore not necessary. Overlaid functionalities such as the profile generator and the controller's state machine are executed on a soft-core processor, the Nios II®. Because this processor is also on the FPGA, there is one central component that executes the entire firmware of the axle controller. We developed the control algorithm with MATLAB®/Simulink® and later translated it with a VHDL autocoder from Synopsys (figure 2).
In addition to E-Darc, Ferrocontrol offers an optional supply module called RePower. This uses energy recovery and draws only active power from the supply mains.

Development with dSPACE

Development tools and hardware from dSPACE were used in the development of E-Darc (figure 2). Our drive system is built up of separate hardware modules such as the field bus communication, encoder evaluation, and power unit. To check how the maturity of individual modules was progressing, we used simulation on a dSPACE HIL test bench, which decisively sped up the development process for the whole system. The classic development process for an FPGA platform consists of steps for VHDL coding, synthesis and place&route. This enables us to develop modules and algorithms separately from one another and to test them extensively in very early development phases, repeatedly feeding the test results back into the development process. We ran integration tests to test the interaction between the single modules. The tests were created with the aid of the in-Step test database from microTOOL and then automated with dSPACE AutomationDesk. The achieved seamless process makes it easier to verify the functional reliability of safety-critical modules according to SIL 3.

Modular Design of the E-Darc System

The E-Darc's modular axle controller design contains not only pluggable incremental encoder cards, but also field bus cards. It supports the following encoders:

- Resolver
- SSI
- Hiperface®
- EnDat® 2.1
- EnDat® 2.2 (Safety)

> "With the dSPACE HIL test bench, we ensure that E-Darc drive controller complies with strict quality guidelines, for example withregard to safety technology."
>
> *Andreas Pottharst, Ferrocontrol Steuerungssysteme*

Two slots are available for a wide variety of application cases. The plug-on field bus module ensures that the system is upgradable and independent of any specific field bus system; the modules currently available are for CANopen, SERCOS III and Ethercat. To ensure the axle controller has high interference im-

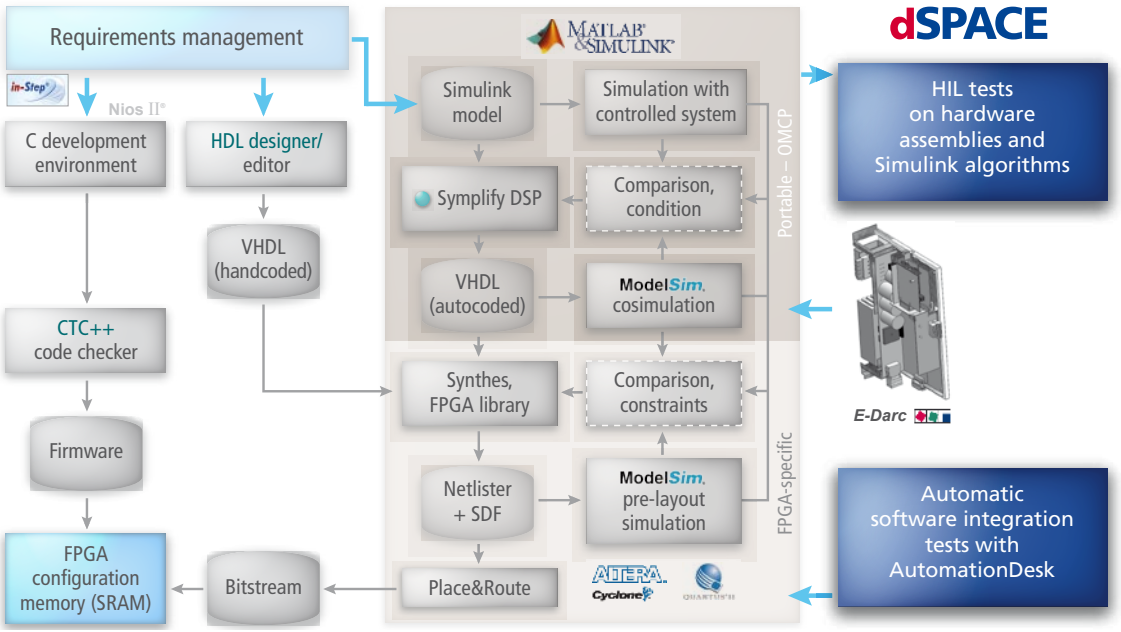


Figure 2: The development process for the E-Darc drive controller.

munity, the individual modules are connected to one another via purely digital interfaces (SPI, Serial Peripheral Interface). This means we can test and develop individual modules independently of the axle controller. Using the DS4121 ECU Interface Boards and a DS551 ECU Interface Plug-on-Device (POD) connected to an FPGA Evaluation Board (figure 3), we can simulate all the SPI communication nodes for each module and therefore test all the modules separately. The FPGA Evaluation Board has a standardized SPI interface for this purpose, in addition to connecting to the POD of the IP core. The POD communicates with the ECU Interface Board via a fast LVDS at a frequency of 20 MHz.
With the dSPACE Real-Time Interface Blockset, we can exchange various parameters under MATLAB/Simulink via a "shift register" similar to a dual-port memory.

Optional Safety Module

This modular system (figure 4) can optionally be equipped with a safety module that has safety technology certified according to Performance Level e (ISO 13849) and SIL 3 (EN 61508). The module can be parameterized freely and provides a variety of safety functions (figure 5).

Software Integration Test According to Quality Guidelines

For certification of the safety module, it is the entire development process that is examined, not just the hardware itself. This process (figure 2) of hardware and software development for E-Darc is subject to the strict quality guidelines that were previously established in the group's medical engineering division and then adopted by Ferrocontrol. A decisive part is played by integration testing, in which hardware and software are brought together for the first time (black-box tests) and the basic functionality is verified. For the specification and execution of these tests, the test case database was generated with in-Step and the integration tests were automated with AutomationDesk. Requirements management was carried out completely in in-Step. We link the individual requirements with test cases of varying levels of detail to make the development process seamlessly monitorable and traceable.
The test bench shown in figure 3 is used as a platform for the test sequences generated with AutomationDesk. At its core is a modular system from dSPACE, consisting of

Glossary

FPGA – Field programming gate array, designed to be configured by the user after manufacturing.

VHDL – Very High Speed Integrated Circuit Hardware Description Language.

SIL 3 – Safety integration level for assessing the reliability of electric/electronic/programmable electronic systems.

CNC – Computerized numerical control is an electronic method of controlling tool machines.

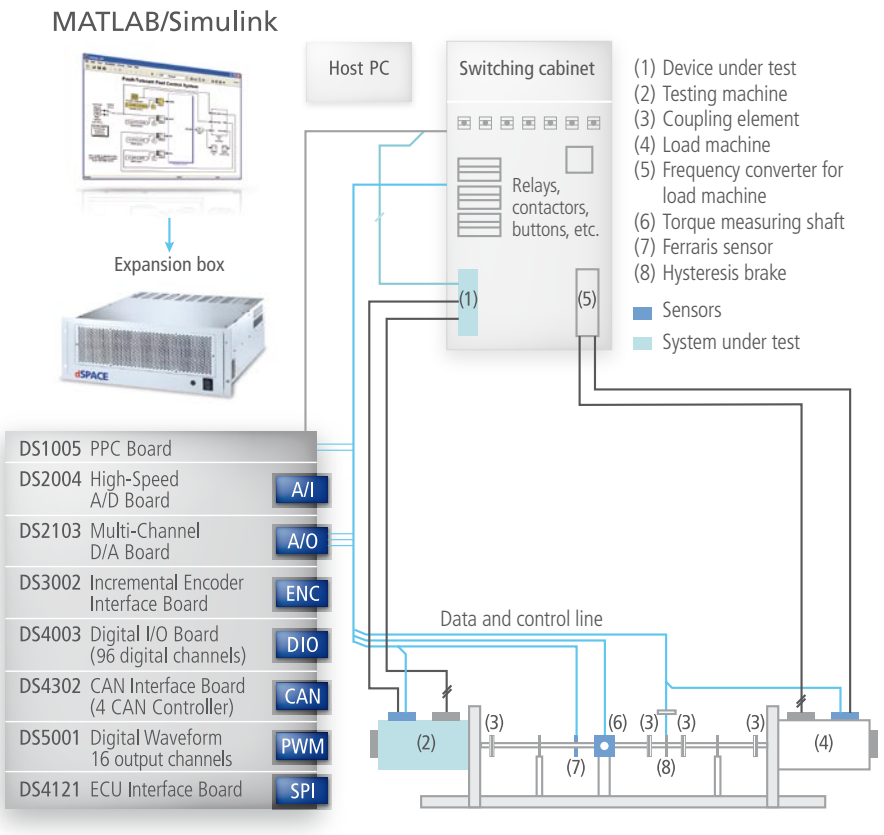


Figure 3: Integration and HIL test bench.

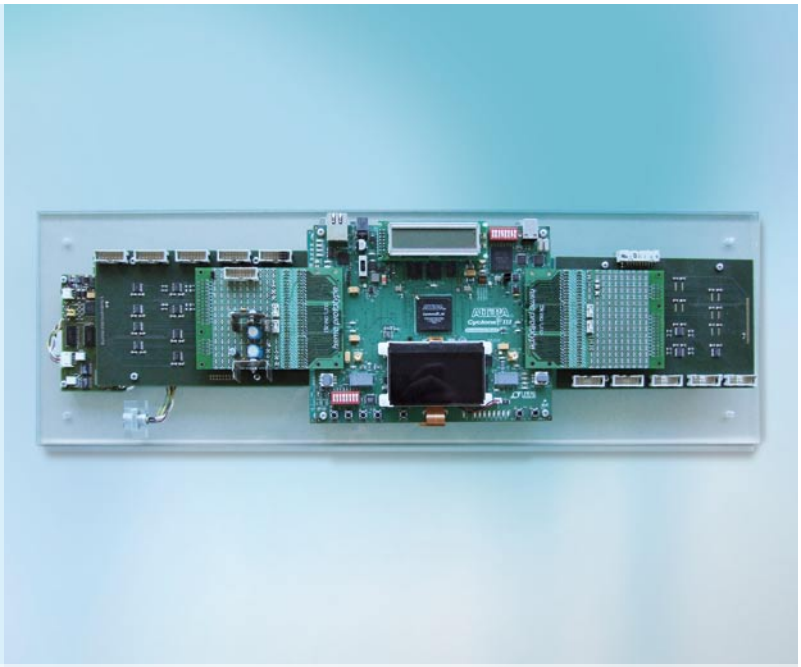
a DS1005 PPC Board to which the I/O boards are connected via the PHS (peripheral high-speed) bus. This system's versatile and flexible I/O, which can be used to control and monitor all of the E-Darc's external interfaces, makes it possible to achieve the extensive test depth that is indispensable to testing safety-critical systems:

- Using the load machine, for example, it is possible to simulate very different and complex load profiles that represent processes on real customer machines. After

Figure 4: FPGA Evaluation Board (Altera 3C120) with DS551.

Summary

- Extensive module tests, based on prototyping with a connected FPGA platform, speed up the development of the E-Darc drive system. Errors are detected earlier.
- A complete test case database with automated tests derived from the test cases is an important element for the certification of drive assemblies in the E-Darc for functional safety.
- Automated tests permanently reduce the testing workload involved in introducing new firmware versions.



these test runs, there is no more danger that an error could damage a real machine or destroy a tool.

- The RTI CAN MultiMessage Blockset made it possible to represent the necessary CANopen master, into which a DBC file based on the current object directory was integrated in Simulink. This CANopen master can simulate the entire CNC control of a machine.

When a test sequence has been completed, AutomationDesk generates a test report showing whether the new firmware version can be released for the modules in question. Entering the test results into the test case database manually to document the current status of the firmware is very time-consuming, however. A software interface to transfer the test results to the database automatically, such as the one available for the DOORS requirements management software, is planned for the future. ■

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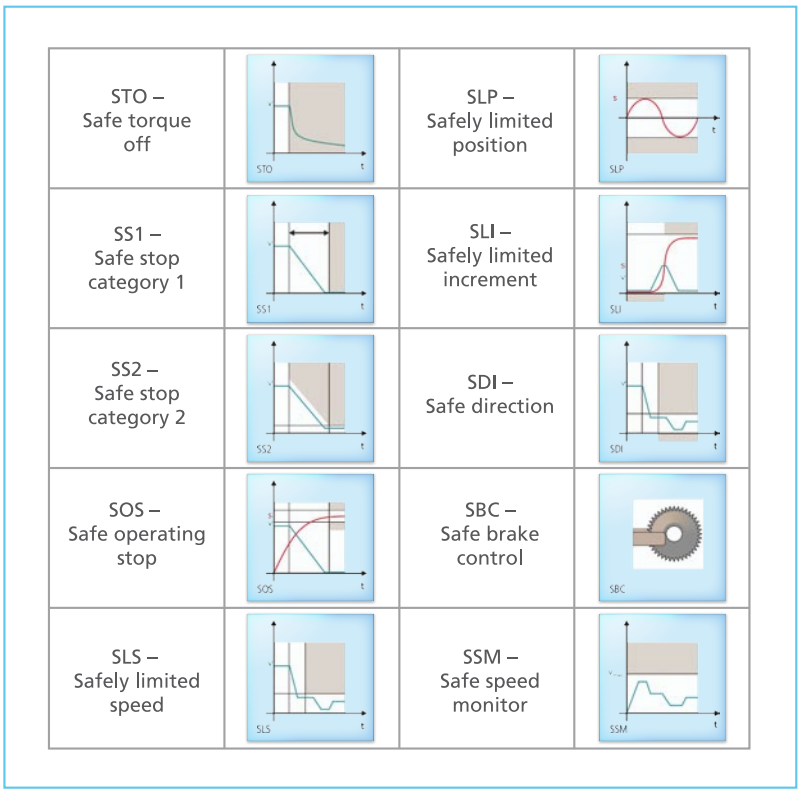

Figure 5: Safety functions of the E-Darc safety module.

Company Profile

As a manufacturer of control systems, Ferrocontrol has been an innovation partner to the window manufacturing and timber processing industries for 36 years. As of 2006, the company belongs to Eckelmann AG, whose headquarters are in Wiesbaden. Ferrocontrol's products and services cover the entire spectrum of window manufacturing, controls for stock-keeping, wood-cutting centers, saws, welders and corner finishers, as well as metal fittings machines; up to buffer systems for the shipment process, systems for logistics, production control, and control systems.
In the development of industry-specific solutions tailored to the requirements and wishes of customers and the market, the company's policy is to develop, plan, and manufacture its own hardware and software components.