DSP Based Flexible Digital Control Systems for Advanced Power Electronics, Motion Control, Industrial Automation and Educational Applications

Leszek Debowski, Marek T. Hartman
The Electrotechnical Institute, The Gdansk Branch
PL-80-557 Gdansk, 1 Narwicka Str.
POLAND
Tel. +48/58/3430645, Fax +48/58/3431295
leszek.debowski@iel.gda.pl / marek.hartman@iel.gda.pl

Guidance Headings: motion/power conversion/industrial process controllers

Abstract
Advanced digital control systems based on modern DSPs and complex programmable logic devices (CPLDs/FPGAs) are being more and more frequently applied in the branch of power electronics, motion control (e.g. electric drives, active filters, power conditioners, specialised power supplies) and industrial automation (complex process controllers). High speed signal processing, programmability and flexibility are very important features in today's control systems dedicated for the mentioned areas. The paper presents the new architecture of digital control systems based on the TMS320 DSPs and CPLDs: flexible motion control boards family (DLH) and digital controller for complex industrial processes. The DLH family is designed for rapid prototyping in power conversion and digital motion control. The computational power of the DLH boards meets in real time the sophisticated requirements of modern control algorithms and strategies (e.g. "vector control", DTC, fuzzy-logic and neuro-fuzzy controllers, estimators, adaptive control). The DSP-based industrial process controller has similar internal architecture, but it's peripherals are dedicated for industrial automation applications. The presented control systems provide extended compatibility with the TMS320 code generation (Assembler / C Compiler / Code Composer / fuzzyTECH MCU-320) and debugging tools (XDS510). Some application examples including educational cases showing the flexibility and effectiveness of DSP/CPLD/FPGA approach are also presented and summarized.

1. Integrated Motion Control Board (DLH-01)

The DLH-01 is the complete single-board control system (Fig. 1, 3) dedicated for power conversion and motion control applications. It provides all the functional modules necessary for prototyping, debugging and stand-alone operation in the target power conversion equipment. The architecture of the DLH-01 is based on the TMS320C2000 fixed-point DSP family and consists on the following basic components:

- 16-bit fixed-point DSP TMS320F206/C203/C206 with up to 25ns single cycle time,
- advanced CPLD integrated circuit FLEX10K with up to 30,000 logical gates capacity,
- specialised motion control co-processor ADMC200/201 or TMS320F24x/F240x DSP.

The real-time control tasks can be divided between the mentioned "intelligent processors". For example, DSP functions (adders, multipliers, comparators, filters) can be implemented as program sequences in the DSPs, but also as very fast "parallel hardware structures" in the CPLD. Additionally, it is possible to configure another modules inside the "programmable logic": PWM subsystem, "dead-time" generator, power switches diagnostic subsystem and communications blocks. Another DLH-01 features include:
Fig. 1. The DLH-01 Block Diagram

Fig. 2. The DLH-02 Block Diagram

Fig. 3. The DLH-01 Control Board

Fig. 4. The DLH-02 Motherboard
- 2 complete independent and flexible interfaces for power inverters both with 6 control and 6 error lines in fundamental configuration dedicated for complex AC/DC/AC converter,
- 10 analog inputs (with 12-/14-bit resolution) dedicated for current/voltage transducers,
- 1 general purpose 0..10V/4..20mA analog input, 1 general purpose 4..20mA analog output,
- inputs: 6 synchronisation or general purpose and 9 general purpose only,
- outputs: 12 general purpose (including 3 relay outputs),
- flexible, multi-channel communications interfaces (RS-485/RS-232),
- up to 256K bytes serial E²PROM or FLASH memory, real-time clock with battery backup,
- all analog, digital and communications channels are optically isolated.

2. Mother- (DLH-02) and Daughterboard Architecture (DLH-03/-04/...)

The philosophy of the second architecture is based on a flexible motherboard/daughterboard configuration to meet various requirements of modern power conversion equipment. The motherboard (DLH-02) is a complete unit (Fig. 2, 4) equipped with analogue, digital and communications interfaces similar to the DLH-01, but without the processor and program/data memory subsystem. The DLH-02 provides the flexible parallel interface based on CPLD resources for buses up to 32-bit, dedicated for daughterboard (e.g. DLH-03, -04) or other external processor system connection. The CPLD integrated circuit features also include up to 70,000 logical gates capacity. The daughterboard (DLH-03) is a processor unit (Fig. 5) consisting of the 32-bit floating-point digital signal processor TMS320C31 with up to 80MHz system clock, up to 512K×32-bit EPROM/FLASH memory, up to 512K×32-bit zero-wait-state RAM, watch-dog timer, 32-bit data/address/control buses connector and synchronous communication interface. The processor unit is also provided with a debugging interface in order to download, execute and debug target applications using appropriate software development tools. The DLH-03 processor board is electrically and mechanically compatible with the motherboard DLH-02. The similar CPU module DLH-04 based on the TMS320C50 (Fig. 6, 7) was designed as M.Sc. student final project in cooperation with the TU Gdansk, Department of Electronics (Poland). Another processor boards (e.g. with the most popular fixed- and floating-point DSP) and PC-cards can be connected with the DLH-02. Ongoing development covers CPU modules (equivalent of DLH-03/-04) making use of other popular groups of fixed- and floating-point digital signal processors.

All members of the DLH control boards family are equipped with JTAG/MPSD interfaces to support in-system programmability and advanced debugging features. Combined with appropriate software-hardware tools (C language compiler, XDS510 emulator board, debugging software, Code Composer package, fuzzyTECH MCU-320 tools, programmable logic software), the proposed solution radically accelerates the development and testing of application software.

The group of the DLH boards comes furnished with numerous accessories helpful during implementation and interfacing with the motion control or power conversion system to be
controlled or high-level industrial control system, such as: control panel (Fig. 8) IGBT driver board (7×max. 200A), IPM interface board, fibre optic interfaces, protocol converters for serial serial interfaces, interface for GSM modem, add-on command and expansion modules.

Fig. 7. The DLH-04 CPU Module