Comparison of different microcontroller development boards for power electronics applications

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Abstract

Proper selection of a microcontroller unit (MCU) for an application is one of the critical decisions which controls the success or failure of your project. There are numerous criteria to consider when choosing an MCU. In this paper three microcontroller units are compared and analyzed to find out the best candidate for power electronics applications. First, the criteria for selection are defined. Then according to the criteria selected, analysis is carried out. Finally benefits and drawbacks of each model are discussed and the best MCU is chosen.

Keywords
Digital Signal Processor (DSP), Microcontroller Unit (MCU), Microcontroller Starter kit

Introduction

Main interest in department of Electrical Drives and Power Electronics of Tallinn University of Technology lie in the design of different kinds of power electronics converters. The objective is to try out some new ideas or optimize conventional converter topologies to increase the efficiency and lower the costs. The constantly varying demands set for converters also presume a flexible and highly effective control system. The standardized and manufactured control systems are mostly optimized for certain types of applications i.e. they are not flexible and cannot be adjusted to the varying demands. The only solution is to design one’s own control system using a microcontroller, which can be programmed freely and with no constraints.

The purpose of this paper is to compare and analyze different microcontroller units on the market in order to find out the best candidate for future use in the projects conducted at the department of Electrical Drives and Power Electronics.

1 Criteria of selection

Today you can find a microcontroller in almost every electronic device. Because of the very wide area of application, the number of different types of microcontrollers on the market is enormous. To find out the best control unit for power electronics applications, first some criteria for selection must be established. Two groups of criteria are involved: technical and economic:

Technical criteria

1. Development software – should be easy to learn and use. Software must include everything needed for the project: a debugger for program code simulation and failure analysis, C language compiler, almost a standard language in the hardware programming today, C language editor to write the program code, and finally, flash burner software to write the program into the microcontroller memory.

2. Working frequency – microcontroller speed depends on its working frequency. The higher the frequency, the better performance can be achieved.

3. The number of independent pulse width modulation (PWM) channels – PWM is used to control electrical parameters in power electronics. The bigger the number of PWM channels, the more flexible the microcontroller is. It is also important to have a PWM phase shift possibility.

4. Timer units – general purpose timers are needed to measure time or create delays inside the control program. The more timers, the more flexible the microcontroller is.

5. Interrupt system – interrupts temporarily suspend current program execution and CPU (central processing unit) branches to an interrupt service routine to service an interrupt requesting device. Interrupts could have prioritization levels that allow the user to specify the order in which multiple interrupt requests are to be handled.

6. The number of external interrupts – external interrupts allow the CPU to react to external events, e.g. some external impulses could be measured. The higher the number of external interrupts, the more flexible the microcontroller is.
7. Analog to digital converter (ADC) – is used to convert analog signals from the sensors to digital to enable the CPU analyze them. Basically, the number of ADC channels is equal to the number of sensors that can be connected to the microcontroller.

8. The type of the microcontroller – Digital signal processor (DSP) or general purpose controller. DSPs have higher performance, especially in mathematical operations.

9. Integration readiness into a user specified application – it should be easy to integrate the module into any user specified application.

Economic criteria

1. Price – since university resources are quite limited, the lowest prices possible apply.
2. Availability – the microcontroller and its software should be available on the Estonian market.

2 Tested microcontroller modules

Two microcontrollers and one DSP (digital signal processor) module were tested. In general, all three modules were specially designed for industrial applications, their working temperature range being extra wide, reaching from -40 to +125°C (Industrial Temperature Range), module design is optimized, with enhanced EMI protection and a rich peripheral set for numerous applications.

2.1 eZdsp starter kit from Texas Instruments

The kit includes everything needed for quickly start with Texas Instrument (TI) DSP (see Fig. 1). [1]

Fig. 1 eZdsp starter kit including TMS320F2812 DSP in Socket, Power Supply, Code Composer Studio for C28xx

The contents of the kit:
- DSP chip eZdsp F2812
- Power supply
- Parallel port cable for programming the controller
- CD-ROM with C compiler and Code Composer Studio (specifically designed to work only with the eZdsp target)
- CD with samples
- Price 391USD

2.2 Rapid Development Kit from Phytec

The phyCORE microcontroller module is designed to be plugged into a Phytec Carrier Board (see Fig. 2). The Phytec Carrier Board contains the I/O connectors as well as any other interface circuitry not provided on the phyCORE microcontroller module itself. [2]

The contents of the kit:
- phyCORE-XC167 Single Board Computer module
- Carrier Board PCM-997-XC
- Power Supply
- DB-9 serial cable
- Phytec Spectrum CD-ROM with µVision evaluation version (including C compiler)
- CD-ROM with Phytec FlashTools
- Price 439 USD

Fig. 2 The contents of Phytec phycore-XC167 rapid development Kit (a), Phytec Carrier Board

2.3 TMDS-FET470R1B1M Kickstart Development Kit from Texas Instruments

The TMS-FET470A256 Kickstart Development Kit is a complete integrated development environment with all necessary hardware and software for development work (Fig. 3). [1]

Fig. 3 TMS470 Peripheral board (a), JTAG Debugger with USB connector (b):
The contents of the kit
- Processor board with TMS470R1B1M microcontroller
- TMS470 Peripheral board
- JTAG Debugger with USB connector
- USB and 20-pin flat cable
- CD-ROM of IAR Embedded Workbench for ARM with the Integrated Development Environment (IDE), C compiler and complete documentation
- Price 399 USD

3 Analysis and comparison of microcontroller modules

3.1 eZdsp DSP module F2812

The eZdsp module comes with a DSP (digital signal processor) chip TMS320F2812. The DSP is basically a microcontroller that contains architectural optimizations to speed up processing. In contrast to general purpose microprocessor, DSPs are optimized for signal processing applications. DSPs offer many architectural features that actually reduce the number of instructions necessary and they can handle many instructions running parallel. The hardware features of the eZdsp DSP module F2812:

- Working frequency 150 MHz
- 64 KB on board RAM
- 128 KB on chip Flash memory
- Expansion connectors for user specified applications
- Onboard embedded IEEE 1149.1 JTAG controller for real-time debugging
- Onboard IEEE 1149.1 JTAG emulation connector
- +5V power supply

The eZdsp DSP module F2812 consists of a carrier board (83 x 146 mm) with an on-board emulator and DSP chip (TMS320F2812). The on-board emulator provides the real-time debugging and visualisation. TMS320F2812 is optimized for industrial applications, such as digital motor control, digital power supplies and intelligent sensor applications. Up to 16 PWM waveforms can be generated simultaneously, six independent pairs with programmable dead times or four independent phase shifted PWM signals by synchronizing timers. Additionally, the DSP module is equipped with three 32-bit general purpose timers for user applications. The eZdsp DSP module F2812 has one 12 bit ADC with 16 analog channels. The conversion results of each channel will be automatically stored in separate registers. The DSP has 96 interrupt sources, the prioritization of which is controlled in hardware and software. Therefore, the CPU can respond quickly to interrupt events. Three external interrupt sources allow the DSP also to react to external events.

All the input and output signals of the DSP are connected with the expansion connectors. The standardized via-connectors (see Fig. 4) can be used to easily connect the DSP module with any user application.

The development software Code Composer Studio included in the started kit of eZdsp DSP module F2812 is easy to use and quick to learn. There are many examples included, which give a good starting point. The software configuration according to the DSP module is easy. The C compiler has no code limit. The only limitation is that the Code Composer Studio is specially designed for the eZdsp DSP module F2812 and will not work with a module designed one’s own. Thus, it is ideal for a prototype development but for production purposes the full version of the Code Composer Studio is needed.

Numerous materials are available to describe the functionality of the DSP TMS320F2812. It might be a little confusing and hard to find the right document at the beginning but as compared to other microcontrollers, its technical specification is more informative.

Texas Instruments has two distributors in Estonia, which makes it easy to order and purchase their equipment. [1][3]

Fig. 4 DSP module TMS320F2812

3.2 phyCORE-XC167 Single Board Computer (SBC) module

The phyCORE-XC167 is a general purpose processor (GPP) based on the XC167CI microcontroller from Infineon in TQFP-144-50 housing. The Flash can easily be programmed on board. The hardware features of the microcontroller module:

- Working frequency 40 MHz
- 512 KB on board SRAM
- 1 MB on chip flash memory
- Expansion connectors for user specified applications
- +5V power supply
The phyCORE SBC module (60 x 53 mm) is designed to be plugged into a Phytec Carrier Board (100 x 160 mm). The PHYTEC Carrier Board contains the I/O connectors as well as any other interface circuitry not provided on the phyCORE module itself.

All the input and output signals of the phyCORE SBC module are connected with the expansion connectors. However, very specific Molex SMD connectors are used, which can only be achieved from Phytec. Therefore, the connectivity to the user applications is not as easy and simple as it is by the eZdsp DSP module from Texas Instruments. The phyCORE SBC module comes with the on-board 16 bit microcontroller XC167. It is a combination of DSP and general purpose microcontroller. The added DSP functionality reduces the execution time of multiplications and divisions considerably. The XC167 microcontroller is supported with a special PWM generation block CAPCOM6. That provides three pairs of output signals of inverted polarity and non-overlapping pulse transitions (deadtime control). In addition, it has one independent PWM output. An alternative to the CAPCOM6 is two Capture/Compare timers, which can also be used to generate PWM. Each Capture/Compare unit provides 16 PWM channels. Using CAPCOM6 and Capture/Compare timers four independent phase shifted PWM signals can be generated. The XC167 microcontroller is equipped with five 16-bit general purpose timers which may be used for timing, event counting, pulse width measurement, pulse generation, frequency multiplication, and for other purposes. XC167 provides a 16 channel ADC with 8-bit or 10-bit resolution (software specified) and a sample & hold circuit on-chip. An input multiplexer selects between 16 analog input channels either via software or automatically. Conversion results will be stored in the same register. Therefore, every next conversion will overwrite the previous result. XC167 provides 80 separate interrupt sources assignable to 16 priority levels, with 8 sub-levels (group priority) on each level. Up to 10 external interrupt sources allow the microcontroller also to react to external events.

The starter kit includes an evaluation version of the development environment µVision together with the C compiler C166. The evaluation version of C166 compiler, assembler, and linker is limited to 4KB of the object code. Apparently the software included in the starter kit does not suit to the demands set for prototype development. The full version costs about 3500 USD. Because of many configurations, development software is quite difficult to learn. There are too few examples. The C code editor of µVision is not as comfortable to use as the Code Composer Studio from Texas Instruments. µVision has also a built-in software debugger, whereas the evaluations version is limited to 8 KB of the code. For real-time debugging you will need to buy some additional equipment. [2][4]

![phyCORE-XC167 Single Board Computer module (a), Phytec Carrier Board (b)](image)

### 3.3 TMS470 Processor board with 60 MHz TMS470R1B1M

TMS470 is a GPP based on the ARM7TDWI core, which offers an industry-standard architecture, including two instruction sets, 32-bit instructions for fast execution and 16-bit instructions for high code density. TMS470 combines the powerful ARM7 core with intelligent peripherals that reduce the load on the CPU by automating common data handling activities. The hardware features of the microcontroller module:

- Working frequency 60 MHz
- 64 KB on board SRAM
- 1 MB on chip Flash memory
- Expansion connectors for user specified applications
- +9V power supply

Targeted for industrial applications, TMS470 has a rich set of peripherals - up to 32 timer channels, 16 channels of 10-bit Analog-to-Digital Converters, and a variety of communication interfaces. The high-end timer (HET) is a programmable timer co-processor with up to 32 associated timing output pins for timer functions, such as capture, compare, pulse width measurement, PWM and general-purpose I/O channels. The TMS470 provides a 16-channel 10-bit resolution multi-buffered ADC. The interrupt module of TMS470R supports up to 64 interrupt sources and provides programmable interrupt priorities. Additionally, eight external interrupt sources allow the microcontroller to react also to external events.

All the input and output signals of the microcontroller are connected with the expansion connectors. The standardized via connectors can be used to easily connect the DSP module with any user application.

The starter kit includes a complete software pack, including the following programs:

- KickStart 16KB (code limit) C/C++ compiler
- Project manager
- Editor
- Linker and librarian tools
- Debugger
- Complete integration with J-Link (for hardware debugging)
The software is simple and quick to learn. However there is a 16 KB code limit in the C/C++ compiler. Therefore, the software included in the starter kit does not satisfy the demands of prototype development.

Texas Instruments has two distributors in Estonia, thus it is easy to order and purchase. [1]

Fig. 6. TMS470 Processor board with 60MHz TMS470R1B1M microcontroller

4 Conclusion

Two microcontrollers and one DSP module were compared and analyzed. The benefits and drawbacks are listed below:

eZdsp DSP from Texas Instruments

Benefits:
- Very flexible microcontroller
- Enough PWM channels
- Reasonable price
- Two distributors on the Estonian market
- Software easy to use and without code size constraints
- Many programming examples included in the starter kit
- The DSP board can be easily built into the user applications

Drawbacks:
- Confusing documentation

phyCORE-XC167 from Phytec

Benefits:
- Very flexible microcontroller
- 10 external interrupts
- 23 PWM channels

Drawbacks:
- Software difficult to use
- Evaluation software has code constraints
- Additional expenditure to purchase the full version software needed
- Too few examples and little help
- Connectivity to user applications difficult because of the specific Molex SMD connectors
- No distributor on the Estonian market

The best candidate to be used in our projects seems to be the eZdsp DSP module F2812 from Texas Instruments. Its price is lower than that of the Phytec phyCORE-XC167 or TMS470 GGP which have code constraints in the evaluation software, so additional expenditures are involved to purchase the full version software. Moreover DSP has much higher performance than a GGP. In addition, Texas Instruments have the most user friendly and easy to learn development environment. The only disadvantage is that the documentation is too confusing however, that will be compensated by the high performance of the hardware.

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References