TMS320F241 DSP Boards for Power-electronics Applications

Kittiphan Techakittiroj, Narong Aphiratsakun, Wuttikorn Threevithayanon and Soemoe Nyun
Faculty of Engineering, Assumption University
Bangkok, Thailand

Abstract

This paper presents the design of Digital Signal Processor (DSP) boards for power-electronics applications. This board is mainly designed for the experiment in the university’s laboratory, however, its design allows the practical used in the commercial products. This work uses the TMS320F241, which is the TI’s DSP for the control application as the main processor. The overview of the architecture, the board design, the way to use the board, and some examples are presented. This board is currently in used by many power electronics and consumer products, e.g. motor drive, proximity card reader/controller.

Keywords: Hardware design, Digital Signal Processor, DSP, Power Electronics Application, Control System

Introduction

New power electronics applications become possible by the availability of high-speed micro-processor (Kamruing 2001; Paothong 2002; and Threevithayanon 2002). These power electronics applications are embedded into many consumer electronics, e.g. refrigerator, air-condition, microwave oven. The high demand of higher computational speed has been posted. Many semiconductor companies, e.g. TI (www.ti.com), Analog Devices (www.analogdevices.com), Motorola (www.motorola.com) have produced the high-speed processor in the form of Digital Signal Processor (DSP) for control applications.

The Digital Signal Processor for control applications are the high speed processor with the enhancement of the special circuits to handle the power electronics applications such as the PWM circuit to generate the analog signals, the quadrature encoder circuit to decode the rotational distance and speed.

Our works are concentrated on the TMS320F241, the DSP from Texas Instrument. This DSP has the performance in the Mid-range (20MIPS). Although there are many evaluation boards and experimental boards (www.softronx.com; www.spectrumdigital.com, www.technosoftmotion.com) available in the market, those boards are mainly design only for the educational purposes. The proposed DSP board is designed such that it can be used for both educational and embedded in the real product.

The design allows the full uses of all built-in peripheral while optimized the cost of the platform. As the educational evaluation boards, this board costs less than one forth of the one from TI.

The next section discusses about the feature available on the TMS320F241. The third and fourth section concentrates on the feature of the board.

TMS320F241 Architecture

TMS320F241 (Texas Instruments 2000a; Texas Instruments 2000b) is the high-speed 16-bit processor designed specially for the control applications. This DSP composes of the standard features, which are 8 kWords of programmable flash ROM, 512 words of RAM and the built-in multiplier units. The chip can operate at the speed of 20 million instructions
per second. The multiplier circuit is built-in to make the complicate control algorithms possible.

Three standard serial communication are integrated into this processor. First is the standard asynchronous serial communication interface (SCI). This SCI can be configured for interfacing to the RS-232 (point-to-point) or RS485 networks. This serial communication port allows up to 1.25Mbps. Second is the serial peripheral interface (SPI). This is the high-speed synchronous serial communication. This interface allows the transfer of information at the rate up to 5Mbps. This high-speed interface is becoming popular in many modern peripherals, e.g. Multi Media Card (MMC). The third serial interface is the Controller Area Network (CAN). This is the robust communication network using in many industry applications. CAN is capable of building a multi-point local area network. CAN allows transmit up to 40kbps at the distance of 1km, while the bit rate can be increase up to 1Mbps for the shorter distance.

The processor composes of many extra circuits, i.e. ADC unit, PWM unit and QEP unit, to enhance the implement of control applications. Analog to Digital (ADC) unit and Pulse Width Modulation (PWM) unit are the interfacing parts of the processor and the real analog world. Up to 8 analog signals, e.g. Voltage and current can be sampling at the speed of 200,000 samples per second with the resolution of 10-bit. The PWM unit can be acted as the digital to analog converter that is the output of the processor to the analog domain. The PWM unit composes of both the normal PWM modules to generate up to five independent analog signals.

The PWM modules can be combined to generate a three phase signals to drive the three phase power electronics applications. This three phase signals are the six digital signals grouped into three pairs. Each pair, the signal for each phase and its inverted signal, can be directly signal to the power devices, e.g. IGBT driver from Semikron (www.semikron.com) ASIPM from Mitsubishi (www.mitsubishichips.com). The circuit inside PWM modules can generate the proper deadband to protect the short branch of the power devices. This deadband timing can be set up to 40 microseconds.

The built-in Quadrature Encoder Pulse Circuit makes the speed and position measurement easier and faster than writing the detection in software. The encoder is the equipment that converts the rotational mechanical movement into the series of 2-bit binary code. The circuit accepts the maximum frequency of more than 2 million pulse per second allowing the ability of capturing the speed and position of the motor at the precision of 1/10000 revolution at the speed of 12,000 rpm. Practically we are detecting 1/1000 revolution at the speed of 1,500 rpm.

**Board Design**

The board is designed to be used both in the laboratory and in the industry. To be suitable for operating in the laboratory work, this DSP board has to be easily to build, use and expand. The industry applications required the board to be highly reliable, compact and cost effective.

The size of this board is 90x60 mm. It composes of the processor, processor supervisory, RS232 driver, CAN driver, EEPROM, analog filter and regulator. The processor is designed to run at the full speed of 20MIPS. Because the PLL inside the processor multiply the clock frequency by four, the 5MHz crystal is used.

DS1232 is used as the optional processor supervisory. This supervisory has three main functions; watchdog, supply voltage monitor, and manual reset. Although the DSP contains the built-in watchdog, the DS1232’s watchdog
has the longer watch time of 0.5s. The supply voltage monitor resets the processor in the case of supply failures.

RS232 driver and CAN driver is added for the processor to connect to the RS232 line or CAN. The processor contains only the circuit to manage the protocol timing. The analog interface, e.g. voltage level and isolation, is handle by the separated driver.

I²C serial EEPROM is used for the non-volatile storage of up to 128 kBytes. Some applications (Paorthong 2002) use the processor main (flash) memory instead of EEPROM, however, the reliability of the system can be decreased with the poor programming software.

The analog filter at the input of the analog to digital converter is designed to filter the noise at high frequency. It also adjusts the proper external impedance for the sample and hold circuit inside the ADC.

Voltage Regulator allows the board to accept the input from 7-18 V (with LM7805) or 6-15 V (with LM2940). The processor and its peripherals consume the total of 120 mA. The extra heat ventilation need to be added if the high reliability is required or there are the high power consumption devices taken power out of this board.

Software Development

The process of developing software is as follow:

Currently there are three type of programming: Assembly Language, C language and visual development. Assembly and C language are supported by the Texas Instrument’s own assembler and compiler. Visual Development Tools is available by the third party. After the compilation, the binary code will be generated in the form of Intel Hex file format. This Hex file will be loaded into the flash ROM of the DSP. The external programmer, the JTAG programmer and RS232 serial programmer are the three common methods of programming the chip.

The first method requires the external programmer, which is quite expensive and not possible for the in-circuit programming. It is proper for the mass production. The JTAG method and RS232 are both in-circuit programming. JTAG requires external JTAG programmer, which is bulky.

The RS232 for in-circuit programming is the method we used for this DSP platform. This method uses the features of the DSP to write the flash ROM by the software. The process requires small software called ‘Serial Boot Loader’ (SBL) installed on the DSP. For TMS320F241, SBL need to be loaded into the chip for the first time by other methods, i.e. JTAG or programmer. The new version of DSP, i.e. TMS320LF2406, is built-in this software inside the masked ROM by the manufacturer. Once the SBL is installed the Hex file can be read from the serial port and programmed into the flash ROM. This method requires the additional of 256 bytes of the flash ROM. The advantage of this method is the capability of on-site, in-circuit upgrade of the firmware.

Hardware Expansion Connectors

The DSP board contains two types of connector. The first type is the group of connectors that are designed for connecting with the daughter board. The second type is the connectors that used to connect with the outside peripheral such as serial port or temperature monitor port.

The first group composes of four separated connectors. All connectors contain the signal pins, ground pins and power supply
(5 V) pins. Ten ground pins are on the outside border while the signal and the supply pins are on the inside.

- The analog to digital connector (‘G’) is connecting to the analog filter before going into the DSP. This connector is used for connecting the analog signals. The first and the last pins are the supply pins. Eight channels of the Analog signals are in the order from 0 to 7.

- The power drive connector (‘E’) is the connector to connect with the power device. There are six channels of PWM signals, which can be combined to drive the three phase signals (with dead band). Two separated PWM signals can be used as the PWM signal generators or as the input/output pins.

- The general purposed digital Input/Output connector (‘F’) is designed for handling the digital input or output signals. The first and the last pins are the supply. The eight input/output pins are from port A bit number 2 to bit number 5 and port C bit number 2 to bit number 5 in the order. The pin number 3 and 4 of port A can be configured to accept the signal for the quadrature encoder to measure the rotational speed or distance.

- The last connector (‘B’) contains the input only pin (BIO), output only pin (XF), watch dog control pin (CLKOUT). Two pins are dedicated for the CAN communication. There are two sets of $I^2C$ communications: (SDA0, SCL) and (SDA1, SCL). This $I^2C$ communication is software-oriented implementation.

The second group of connectors are: RS232 connector, $I^2C$ connector, CAN connector, and thermister connector. This connector is provided mainly for connecting with the external cable.

**Conclusion**

The TMS320F241 board is designed by the research team at Assumption University to use in the power electronics applications. This board is accommodated the need for the
laboratory used and for the industrial need. By adding the power devices and signal conditioning circuits, the power electronics applications can be accomplished easily.

Appendix

The following is a layout of the connection on the DSP boards. ‘A’ is for the 6 to 15 V power supply to the board. ‘C’ is the CAN connector. ‘D’ is the RS232 compatible connector. ‘H’ is the I²C connector and ‘J’ is for connecting to the thermistor.

References

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