C8051F005 System-on-a-Chip-Based Trainer for Learning Microcontroller System

KHAIRURRIJAL*), ARIF SURACHMAN, ASEP SUHENDI,
AND HERI PERMADI
Physics of Electronic Materials Research Division
Faculty of Mathematics and Natural Sciences
Institut Teknologi Bandung
Jalan Ganesa 10, Bandung 40132
INDONESIA

Abstract: - C8051F005 System-on-a-Chip-based trainer was developed for helping undergraduate students in learning microcontroller system. The C8051F005 SoC trainer employs the 8051-based microcontroller and provides applications for accessing ports LED (Light Emitting Diode), seven segment display as well as LCD (Liquid Crystal Display), DIP switches, and keypad. In addition, the Microtrainer also provides SMBus (System Management Bus) or I2C (Inter Integrated Circuit), SPI (Serial Peripheral Interface), UART (Universal Asynchronous Receiver/Transmitter), PCA (Programmable Control Array), and JTAG (Joint Test Action Group) protocols for learning communication/interfacing protocols. Featuring with 12-bit AD (Analog to Digital)/DA (Digital to Analog) Converters, comparators, a 2 kilobyte internal data RAM (Random Access Memory), and a 32 kilobyte flash memory, the students can learn the microcontroller easily and apply it in every microcontroller-based application.

Key-Words: - ADC, DAC, Flash memory, Interfacing, JTAG, Microcontroller, Protocols, RTC, SoC

1 Introduction

Physics Study Program of Faculty of Mathematics and Natural Sciences at Institut Teknologi Bandung provides a 4-credit unit (CU) elective course with a one-CU laboratory work named as FI3272 Microprocessor and Interfacing. The course describes a microcontroller IC (integrated circuit) consisting of microprocessor and peripheral devices such as random access memory (RAM) and read only memory (ROM) [1]. Interfaces between the microprocessor and peripheral devices are also explained. Practical aspects of microcontroller programming are carried out in the laboratory to strengthen concepts delivered in classroom.

A long tradition done in the course is to give explanation on the 8051-based microcontroller, which is one of the most popular microcontrollers. The ATMEL AT89S8252 microcontroller is usually employed in the laboratory [2,3]. Recently, C8051FXXX System-on-a-Chips (SoCs) have been launched to the market. These SoCs are becoming widely accepted among individual users and industries because they embed the most popular 8051-based microcontroller. With the purpose of introducing the C8051FXXX SoCs into classroom, a trainer based on C8051F005, which presents characteristics of the C8051FXXX SoCs, was designed and developed. Here, we report the design and development of the training board for learning the microcontroller system. Some applications for the laboratory work are also illustrated.

2 C8051F005 SoC-Based Trainer

Figure 1 depicts the block diagram of the trainer. The trainer utilizes the C8051F005 SoC, which is a member of the C8051FXXX SoCs. The 8051F005 SoC has the following subsystem:[4]

a) an 8-bit 8051-based microcontroller.
b) a 12-bit ADC (analog to digital converter),
c) two 12-bit DACs (digital to analog converters),
d) a 32-kilobyte in-system programmable flash memory,
e) a 2-kilobyte RAM (random access memory),
f) timers with PCA (programmable counter array) protocol for timer and counter.
g) two comparators, and
h) an analog multiplexer with 8 inputs.

The C8051F005 SoC is also equipped with SMBus (System Management Bus) or I2C (Inter Integrated Circuit), SPI (Serial Peripheral Interface), UART (Universal Asynchronous Receiver/ Transmitter), and JTAG (Joint Test Action Group) protocols for communication/ interfacing.

As seen in Fig. 2, the core of the training board is the C8051F005 SoC (1). The training board provides 3 input devices: 8 DIP-(dual in-line package) switches (2), a 4-row x 3-column keypad (3), and 4 push buttons (4) for timer or external interrupts. It is also furnished with various displays as output devices: 8 LEDs (light emitting diodes) (5), 4 seven-segment displays (6), and an LCD (liquid crystal display) (7). The board has the M25P40 flash memory (8) with the capacity of 4 Megabytes to store data and the PCF8583 RTC (real time clock) (9) for calendar, hour, and clock applications.

Other additional input and output devices can be handled by the training board through Port 0 (10), port 1 (11), port 2 (12), and port 3 (13) on the training board.

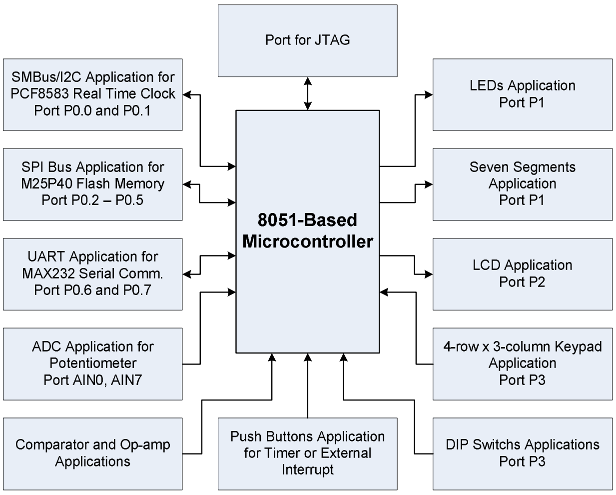

Figure 1. Block diagram of the C8051F005 SoC-based trainer.

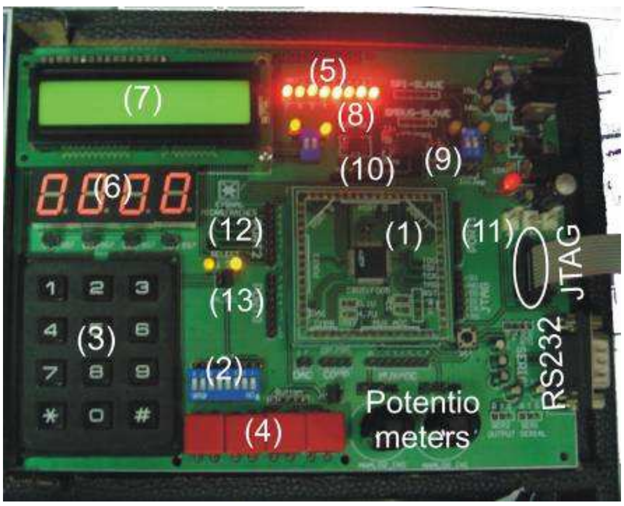

Figure 2. Front view of the trainer.

Before a program is uploaded into the trainer, the program is edited in a computer, compiled to ensure that all syntaxes are fulfilled, and executed to verify that logics are true. The software for these purposes is IDE (integrated development environment) of Silicon Laboratories as given in Fig. 3.

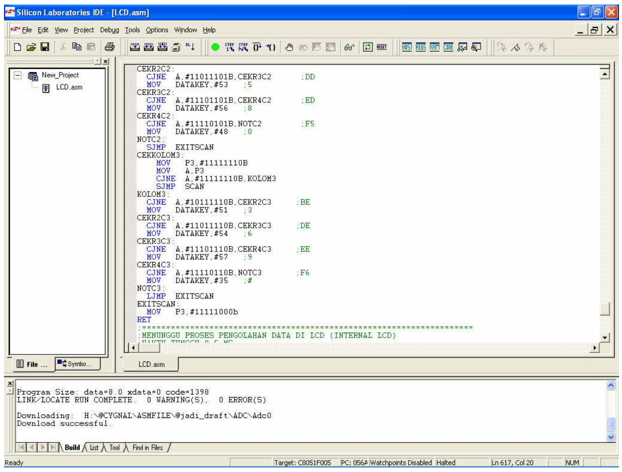

Figure 3. A program is being written by using the IDE of Silicon Laboratories.

After the program has no syntax errors and does desired logics, the program is uploaded to the trainer by using the JTAG protocol as shown in Fig. 4. Communication between the RS232 serial port of the computer and the JTAG port of the training board is facilitated by the EC2 serial adapter of Silicon Laboratories and the IDE software.

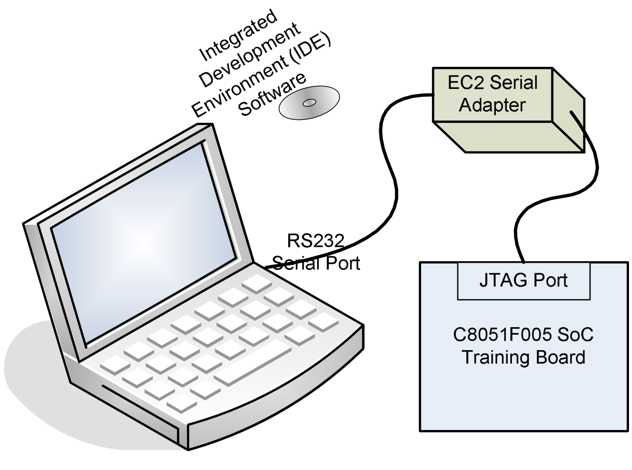

Figure 4. Use of JTAG protocol between computer and the trainer.

3 Learning Microcontroller System

The first step in learning the microcontroller system is to understand its architecture and a set of instructions, which is grouped into logics, Boolean transfer, data transfer, arithmetic, and program branching operations. Using the IDE software, a program containing the 8051-based instructions is written, compiled and executed. The program is then uploaded into the trainer and the effect of each instruction can be observed in the trainer.

Further learning steps are to access various ports, to use analog to digital converter (ADC), digital to analog converter (DAC) and analog comparator, to program timer/counter, to apply interrupts for various applications, and to communicate among internal devices such as the flash memory and the real time clock and external devices.

Five input/output devices are provided by the training board: eight LEDs, four 7-segment displays, an LCD, eight DIP switches, and a keypad. These input/output devices are applied in accessing ports of the C8051F005 SoC, in which each port has 8 lines.

a. LEDs.
For the objective of using the LEDs as output devices, port 2 must be programmed as an output. Then, each LED can be switched on or off by each bit data sent by the microcontroller.

b. Seven-segment displays.
Like the LED displays, port 2 must be programmed as an output for the 7-segment displays. Eight bit data is then sent to 47LS247 BCD (binary coded-decimal) of National Semiconductor, which is a driver for a 7-segment display, by the microcontroller to display numerical and alphabetical characters.

c. LCD.
Again, port 2 must be programmed as an output to send data to be displayed by the LCD. In addition, port 3 must also be programmed as an output port, in which 3 bits (P3.5, P3.6, and P3.7) are used as control bits of the LCD. These control bits are also sent by the microcontroller.

d. DIP switches.
Eight DIP switches are utilized as input devices. Port 3 must therefore be programmed as input. The condition of every switch (on or off) is sent to the microcontroller.

e. Keypad.
Again, port 3 must be programmed as input. Each pushed key is buffered by 74LS245 and sent to the microcontroller.

In order to learn the actions of multiplexer and ADC of the C8051F005 SoC, two potentiometers are provided by the training board as two input devices and the available voltages are lower than 2.4 V. These potentiometers are assigned as input ports AIN0 and AIN7. These input ports must be selected as a part of activating the analog multiplexer and the analog voltage of the potentiometer is sent to the ADC and finally the digital data is received by the microcontroller. Although the action of DAC is opposite to that of ADC, learning DAC is easier. Two pins are available on the training board as outputs of the DACs. The study of comparator is performed by applying analog voltages to inputs of the comparator. Output of the comparator is then fed to the ADC.

The application of timer can be learned by giving delay for switching the LEDs, seven segment displays and LCD on or off. Time stamping can also be done by the assistance of the RTC device. The timer can be functioned as a counter for example in counting a process of pressing an available push button. In interrupting an on going process, the available push button is pressed.

Finally, in order to learn the four communication protocols, port 0 of the C8051F005 SoC is provided. Bits P0.0 and P0.1 are intended for the SMBus or I2C protocol. Bits P0.2 – P0.5 are aimed for the SPI protocol. The rest (bits P0.6 and P0.7) are set for the UART (RS232 serial communication).

a. SMBus or I2C.
This protocol is applied for the communication of the SoC and the PCF8583 RTC that supplies calendar, hour as well as clock.

b. SPI.
In the communication between the SoC and the M25P40 flash memory, the SPI protocol is employed.

c. UART (RS232).
This protocol is usually operated to communicate serially to another device such as computer.

d. JTAG.
The training board provides the JTAG port for this protocol. Another device to be connected must also have a JTAG port. Otherwise, an adapter is needed. In the case of a computer with the RS232 serial port, the EC2 serial adapter must be used to communicate to the JTAG port.

4 Summary

We have designed and developed the C8051F005 SoC-based trainer for helping undergraduate students in learning microcontroller system. Since the C8051F005 SoC has an 8051-based microcontroller, a set of instructions of the microcontroller must be initially learned. Next, in order to learn on accessing ports, the trainer provides input and output devices such as DIP switches, a keypad, LEDs, 7-segment displays and an LCD. A 12-bit ADC and two 12-bit DACs with an analog multiplexer enable the students to study how the multiplexer, ADC, and DAC work. Analog processing is also easily studied by using the comparator. A 2-kilobyte internal data RAM and a 32-kilobyte flash memory let the students create application programs freely. Finally, the trainer also provides SMBus or I2C, SPI, UART, PCA, and JTAG protocols for learning communication/ interfacing protocols. The SMBus or I2C protocol is applied for communication between the microcontroller and the PCF8583 RTC. Interfacing the microcontroller and the M25P40 flash memory is carried out by the SPI protocol. Serial communication to the microcontroller is performed by the UART (RS232). The JTAG protocol is for interfacing between the microcontroller and another JTAG-based device/board.

Acknowledgement

Financial support for presenting this paper by the B Program (Promoting Excellence) of Institut Teknologi Bandung, which is sponsored by the Directorate General of Higher Education, the Ministry of National Education of the Republic of Indonesia is acknowledged.

References:

[1] B. E. Noltingk, *Instrumentation Reference Book*, Second Edition, Educational and Professional Publishing. Ltd., Reed, 1995.

[2] M. O. Durham, *System Designs and the 8051*, Second Edition, Techno Press, Tulsa, 2004.

[3] Khairurrijal, M. M. Munir, A. Suhendi, H. Thaha, and M. Budiman, “An AT89S52 Microcontroller-Based Single Board Computer for Teaching an Instrumentation System Course”, *Computer Applications in Engineering Education*, Vol. 15, 2007, pp. 166-173..

[4] Silicon Laboratories, Mixed Signal 32 KB ISP Flash MCU Family C8051F000/1/2/5/6/7 Data Sheet, 2003.