AC 2007-3083: DESIGN OF DATA ACQUISITION SYSTEM FOR COMPUTER ENGINEERING EDUCATION

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Design of Data Acquisition System for Computer Engineering Education

Abstract

A microcontroller based data acquisition system presented is designed for computer engineering students to enhance their knowledge of both microcontrollers and analog circuits, such as A/DC (analog-to-digital conversion), D/AC and integrated-circuit temperature sensors. The system also provides students real-world examples of microcontrollers application and helps students understand how a microcontroller, C language programming, and analog circuits work together to become an embedded system. In addition, it provides a tool for the students to program hardware specific driver codes and to test the system to meet design requirements. The design involves integration of an 8051-based microcontroller, a 12-bit serial A/D converter, an 8-bit D/A converter, an instrumentation operational amplifier, a keypad, and a liquid crystal display. Once the C-language code is compiled, students can download the machine-language code to the system using a PC serial port and do not need any external EPROM burner. The data acquisition system has non-volatile flash memory to hold the code, which allows students to run their code in a stand-alone mode.

Introduction

Computer engineering is a discipline that combines both computer science and electrical engineering and prepares students for careers that deal with software and hardware components of modern computer systems¹. To educate computer engineering students effectively and practically one needs to provide hands-on activity in class. It would be beneficial if they were exposed to real-world engineering problems, which involve both software and hardware components of computer systems. Utilizing a computer platform to build an embedded system could provide hands-on and practical examples for students². In this paper, we employ a microcontroller based data acquisition system as the platform.

Data acquisition involves sampling of signals and processing the signals to generate useful information. These are usually achieved by microprocessor/microcontroller related hardware and software. Courses in microprocessors and microcontrollers are standard parts of computer engineering curriculum in general. Computer Engineering at Virginia State University (VSU) offers computer system related courses such as CPEG 307 (Linear System Analysis) that covers subjects on sampling and discrete-time signals, ENGR 204 (Object-Oriented Programming), CPEG 303 (Intro. to Electronics), CPEG 208 (Microprocessors), CPEG 416 (Adv. Microcontrollers), and CPEG 404 (Data Acquisition and Control System).

The design of data acquisition system allows computer engineering students to weave together the knowledge gained from these courses in the curriculum. The system also provides students real-world examples of microcontrollers applications and helps students understand how a microcontroller, C language programming, and analog circuits all work together to become an embedded system. In addition, it provides a tool for the students to program hardware specific driver codes and to test the system to meet design requirements.

Hardware Platform

The block diagram of the data acquisition system is shown in Figure 1. The D/A conversion circuits are used to generate arbitrary waveforms such as a saw tooth waveform, a pulse, and a PWM waveform. Each waveform is generated by a C language program running on the microcontroller board. The voltage regulators are required to supply +5 and -5 Volts to the analog circuits in both conversion circuits. The serial A/D converter is used to save the number of input/output (I/O) pins of the microcontroller. The notation Px.y in Figure 1 implies x port and y pin of the microcontroller I/O. The microcontroller board, keypad, and LCD module are off-the-shelf products. The microcontroller in the board is DS89C420⁷ that is compatible with Intel 8051.

Figure 1. Block Diagram of Data Acquisition System

The platform includes the following blocks and associated components in each block.

- Digital-to-Analog Conversion
 - 8-bit D/A Converter DAC0800³
 - TTL Buffer 74LS244

- Voltage Regulator for Analog Circuits
 - +5 Volt Regulator 7805
 - -5 Volt Regulator 7905
 - Filter Capacitors and LEDs
- Analog-to-Digital Conversion
 - 12-bit Serial A/D Converter MCP3202 ⁴
 - Instrumentation Operational Amplifier OP07 ⁵
- Microcontroller Board MDE8051 ⁶
 - Intel 8051 Compatible Microcontroller DS89C420 ⁷
 - 16KB Flash Memory
 - 256 Byte RAM
 - In-System Programmable through RS-232 Serial Port
 - Two RS-232 Serial Ports
- LCD Module 08LCD11 ⁸
 - 20 x 2 LCD Character Module
- Keypad 17KP1604 ⁹
 - 4 x 4 Matrix

Analog-to-Digital Conversion Testing

In order to test the serial A/D conversion circuits, a variable voltage source is required. A simple battery pack (1.5 AA x 4 pcs), a potentiometer and a resistor are used in this setup. The voltage source is applied to the input of A/DC circuits.

Figure 2. Analog-to-Digital Conversion Testing Using Battery-Powered Voltage Source

The input voltage is read on the LCD panel as shown in Figure 2. The schematic diagram of the A/D conversion circuit is shown in Figure 3.

Figure 3. Schematic Diagram of A/D Conversion Circuits

A buffer 74LS244 and a pull-down resistor are attached to the digital output of A/D converter to generate TTL compatible digital signal.

Digital Thermometer Implementation

Figure 4. Digital Thermometer Implementation

Once the input voltage is read correctly, an integrated circuit temperature sensor LM34¹⁰ is attached to the A/DC input to measure the current ambient temperature. The sensor's output voltage is linearly proportional to the Fahrenheit temperature. It has the linear scale factor of +10mV/°F and capability to read -50 to +300 °F temperature range. Figure 4 shows that the system is reading a room temperature of 72.7 °F. The component shown in the upper-left corner is the temperature sensor.

Arbitrary Waveform Generation Using D/A Conversion

Figure 5. Arbitrary Waveform Generation Using D/A Conversion Circuits

A saw tooth waveform is generated using the D/A conversion circuit as shown in Figure 5. The D/A conversion block includes an 8-bit digital-to-analog converter DAC0800 and an instrumentation operational amplifier OP07. The frequency of the waveform shown in this figure is 1 KHz. Other kinds of waveforms can be generated by a suitable C program. When timer interrupt routine is used, an accurate waveform for the time axis can be obtained.

Figure 6. Schematic Diagram of D/A Conversion Circuits

The schematic diagram of the D/A conversion circuit is illustrated in Figure 6.

Software Development Platform

The Keil compiler¹¹ is used to compile the source codes in Windows PC. The evaluation version of Keil compiler with a limitation of 2KB hex code generation can be downloaded from its website. Once the C-language code is compiled, the machine-language code (Intel Hex) can be downloaded to the system using a PC serial port and the Windows Hyper Terminal. The hex code goes directly to the flash memory of the microcontroller and, therefore, it does not need any external EPROM burner. The microcontroller has non-volatile flash memory to hold the code, which allows students to run their code in a stand-alone mode without a PC host.

Future Work

When the LCD is attached and all of the LEDs are turned on, the off-the-shelf board, MDE8051, generates excessive heat near the on-board voltage regulator (mark “A” in Figure 2.) Unfortunately, due to the regulator being placed near the microcontroller, it is heated up easily

and, therefore, it could not always run the program stably. In this experiment a small fan that consumes a small amount of current is used to cool down the microprocessor and the regulator. To build a more reliable platform, it would be necessary to design a new microprocessor board.

Conclusions

For several semesters, computer engineering students successfully integrated their knowledge gained from computer system related courses to design a data acquisition system. They employed microprocessor hardware, C programming, A/D & D/A conversion, electronics, and used modern engineering tools such as a cross compiler and a schematic entry software. Building the data acquisition system provided students real-world application examples, such as a digital thermometer and an arbitrary waveform generator.

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