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A modular and low-cost data acquisition card design with multitasking support

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Abstract

This paper describes a microcontroller-based, low-cost and multi-function data acquisition card design. A wide user audience for this product and a wide field of use are considered on the basis of containing many functions. Many kinds of projects in universities need data collection interfaces, which greatly increases the cost of project. Comparing with other data acquisition cards, this design comes to the flexibility to change the number of and the functions of ports which is the part of the designed data acquisition card. Also with this design more than one system can be controlled simultaneously.

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1. Introduction

Using computer technology in the developing world, are becoming increasingly common. Computers are used in all areas of our lives with these developments. In many control applications performed with computers, the computers' communication with the external environment is very important. The need to communicate with physical environment by the computers is observed in our university too. Mainly in Marmara University Faculty of Technical Education Department of Electronics & Computer Education and also many other faculty and departments, this requirement seems to be obvious. Data acquisition cards are needed in computer aided analysis or control applications. It is not usually possible to get computer support for our projects. The main reason for this situation is the inadequate number of data acquisition cards in university. The high prices of these cards are limiting the use in projects (National Instrument products, 2009). Whereas having computer support with data acquisition cards in studies for education will make experiments easier, more understandable and be concluded faster. Also this will help to increase performance in crowded classes. Besides, many students need data acquisition cards in final projects. In this case, the data collection card constitutes a large portion of project costs. Considering the limitations of our university we can realize the necessity of the low cost data acquisition cards with multitasking support. By using low cost data acquisition cards, costs of projects will decrease. For this purpose, some data acquisition card

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designs has been examined (Ocaya, 2005; Mota, Fonseca & Santos, 1998; Benghanem 2009). Because these cards do not meet our needs, we decided to design a more flexible and multifunctional card. In card design, PIC16F877A hosting several integrated units is used (PIC 16F877A Datasheet, 2009). In addition to the main card, many modules are designed. User simply needs to take modules to expand the functionality of this card. Besides this, users can design and use their own cards with the support of interfaces (parallel or SPI). With this modular design, users will buy only needed modules and support their projects with minimum cost. And also lower number of cards will be able to meet the needs of laboratories in universities by the multitasking function. This will help to reduce the cost of equipments for laboratories.

2. Hardware

In design, PIC16F877A, a microcontroller of Microchip company, is used considering low cost and ease to find. Hardware diagram is shown in Figure 1a and breadboard design at trial phase is shown in figure 1b.

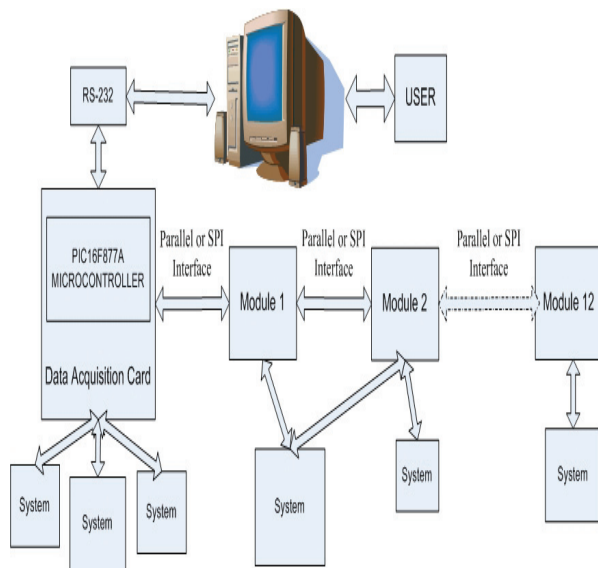


Figure 1a. Hardware diagram

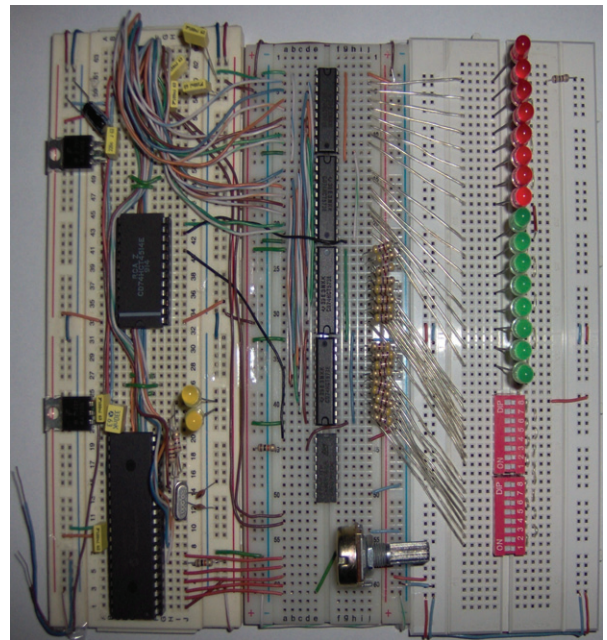


Figure 1b. Breadboard design at trial phase

As shown in Figure 1, microcontroller is used to provide communication between computer and data acquisition card and to control ports. Commands, received from computer, are analyzed and responded continuously in a loop. If microcontroller receives a command, firstly analyses that and then performs the request. Figure 2 shows the flow chart of microcontroller's software and Figure 3 shows circuit design.

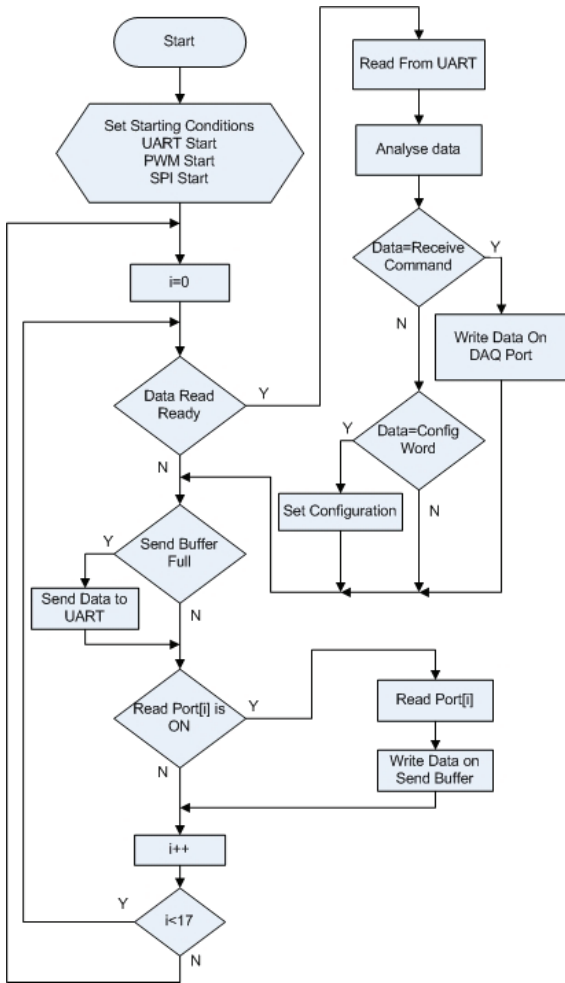


Figure 2. Flow chart of microcontroller software

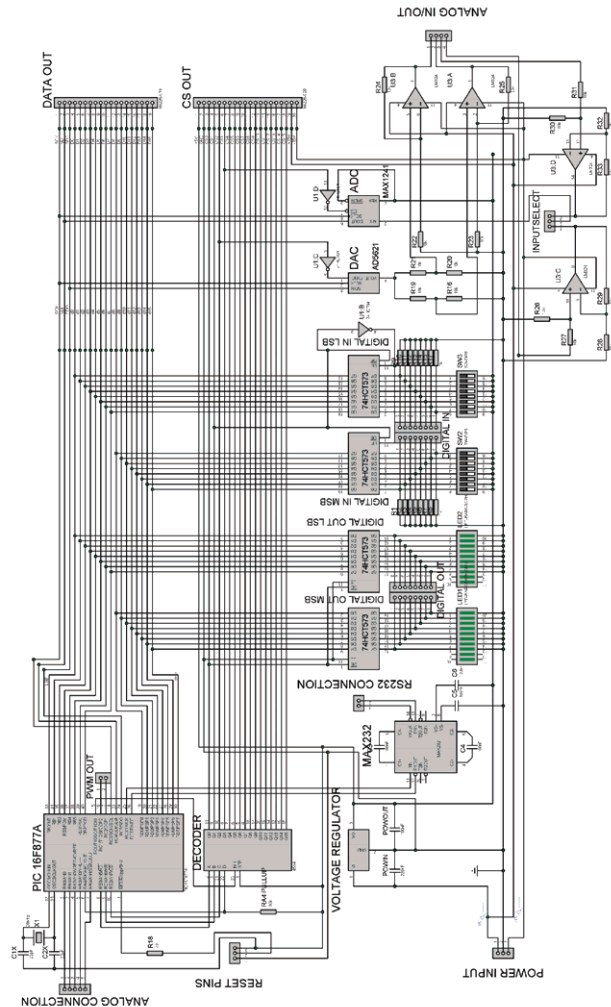


Figure 3. Circuit diagram

3. Connection and communication protocol

The card connection is provided via RS232 standard at the speed of 128Kbps. Communication protocol is set to one start bit, one stop bit and no parity bit so one byte is transmitted with 10bits. With this communication datas are transmitted simultaneously without buffering. In the protocol between computer and data acquisition card, commands are sent with five bytes. Figure 4 shows a command structure built with five bytes.



Figure 4. Command structure

In a command, first and last bytes represent command type, second byte represents port and bit address, third and fourth bytes represent data bytes.

4. Circuit design

In circuit design, expandability and cost have been kept in mind. Considering this, data and address bus structure, which is commonly encountered in microprocessor design, is used (Wakerly, 1977). Some of microcontroller ports are assigned as data and address buses. In this wise, many of modules can be connected to the data bus according to addressing capability. Microcontroller can access any module supporting this structure. In addition to parallel interface, SPI data communication support was also added to provide variety of modules.

5. Modules

Main card has one 16bit digital input, one 16bit digital output, one 12bit analog input and one 12bit analog output. Addition to this there is also five 10bit analog inputs and two 10bit PWM outputs for use on general purpose. If these standard ports do not meet users' needs, it can be expanded with modules designed on SPI or parallel interface. These modules can be digital input/output module or analog input/output module up to 16bit resolution. Module features is determined by the integrated circuits used on. Any of integrated circuit (Analog to digital converter-ADC, Digital to analog converter-DAC etc.) can be used on modules which support SPI or parallel interfaces.

6. Acquisition time

One of the basic features of the data acquisition cards is acquisition time. This parameter is variable on card and depends on how many ports are being used. As shown in Figure 5, acquisition time is mainly occurred in three stages: reading time from ports, communication time with computer and writing time to ports.

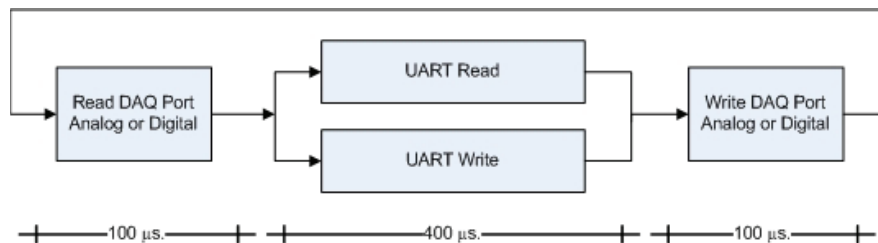


Figure 5. Timing diagram

The time of reading and writing operations are approximately equal and takes about 100μs. This consists the duration of data acquisition from or to ports and data packaging for built a command. With RS232 connection, one byte is sent by 10 bits. At speed of 128 Kbps. it takes 78μs. to transmit a byte data. Because a command is formed by 5 bytes, it takes 390μs. to transmit a command. If only read process is being performed, the acquisition time will equal to approximately 500μs, sum of read time and communication time. On the other hand, if read and write process is being performed together, the acquisition time will equal to 600μs, sum of read time, communication time and write time. The card is designed to serve the ports by turns. For example, if two separated reading and writing process is being performed, first pair of ports will be served and then second pair will be served. So acquisition time will be 1200μs.

7. Accuracy

Five 10 bit analog inputs and two PWM output ports depend on microcontroller so it is not possible to change any feature of these ports. However, all other ports depend on their integrated circuits so features can be obtained by

choosing the appropriate integrated circuits. Accuracy of the modules can be learnt from datasheets of integrated circuits (PIC 16F877A Datasheet, 2009; AD5621 Datasheet, 2009; MAX1241 Datasheet, 2009).

8. Test results

Interface software is prepared with C# and with this interface samples have been taken from data acquisition card in test phase. Figure 6, 7 and 8 show the reading test results.

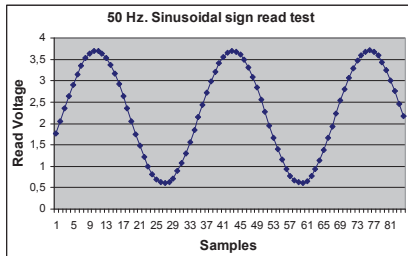


Figure 6. 50 Hz. Sinusoidal sign read test

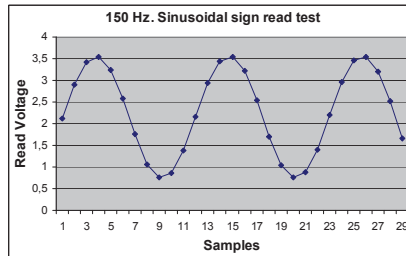


Figure 7. 150 Hz. Sinusoidal sign read test

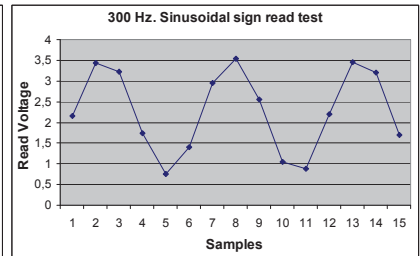


Figure 8. 300 Hz. Sinusoidal sign read test

As seen on Figure 6, 7 and 8, the main restriction of the card is sample rate. Sample rate was obtained as 2000 sample per second maximum. This value will decrease if more than one process is being performed. Sample rate will be divided by the number of ports being used.

9. Conclusion

This paper is focused on designing a low cost data acquisition card for laboratories and projects at university. The goal of project has been reached and laboratories are supported with low cost data acquisition cards (National Instruments products, 2009; Iotech products, 2009; Advantech products, 2009). Also designed card will be used in some graduate projects. Many modules are designed to meet demands of projects.

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