DEVELOPMENT OF A LOW COST DATA ACQUISITION SYSTEM

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Abstrak
Sistem akuisisi data memiliki peranan penting pada sistem pengolahan sinyal. Penggunaan antarmuka paralel dan serial pada komputer untuk berkomunikasi dengan piranti luar merupakan hal yang umum. Tetapi keberadaan antarmuka paralel dan serial saat ini tergeser oleh keberadaan USB yang menawarkan kecepatan dan kemudahan pemakaian. Oleh karena itu, sistem akuisisi data yang menggunakan USB sebagai antarmuka merupakan sebuah kebutuhan.
Sistem yang diusulkan terdiri atas dua bagian utama, yaitu sistem mikrokontroler PIC16F877A dan modul USB. Dengan demikian sistem yang dikembangkan memerlukan sedikit jumlah komponen. Sistem mikrokontroler yang dipilih mampu bekerja dengan kristal 20MHz dan memiliki ADC internal 10-bit.Dengan menggunakan modul USB, program pengiriman data tidak memerlukan program kendali pengiriman spesifik.
Berdasarkan data pengamatan, sistem yang dikembangkan mampu mengakuisisi data dengan baik dan dapat beroperasi dengan dengan PC maupun notebook menggunakan port USB.

Kata kunci: *ADC, PIC16F877A, modul USB*

Abstract
Data acquisition system plays important role on signal processing. The well established interface on PC desktop, printer and RS-232 port, has been widely used in interfacing between PC and external device. The growth of USB port nowadays replaces the role of printer and COM ports. It offers transmission speed and simple in operation. Hence the USB-based DAQ is the need for nowadays application.
The proposed system is arranged two main parts, i.e.PIC16F877A microcontroller system and USB module. The choosen microcontroller is able to operate with 20MHz crystal and it has an internal 10-bit ADC. By using the USB module, the transmission program does not require a specific firmware.
The results show that the developed system is able to acquire the analog signal well and it can work with PC desktop or notebook through USB port.

Keywords*: ADC, PIC16F877A, USB module*

1. INTRODUCTION

Data acquisition system plays important role on signal processing. The well established interface on PC desktop, printer and COM port, has been widely used in interfacing between PC and external device.

Since the RS-232 serial interface is no longer a common port on Personal Computer or notebook (Rojvanit, 2004) the USB becomes popular. The growth of USB makes the standard of device interconnections. It can be found on every PC desktop and notebook as with compared to conventonal parallel port.

Najeb et al developed a daq unit for heart sound analysis (Najeb et al., 2005). The developed daq unit was complemented by a signal condiioning and it was able to convert at 2kHz sample period. The external 16-bit ADC was implemented and a two channel multiplexer determined the input of ADC. A microcontroller was employed to control the multiplexer, ADC and parallel port interface. The conventional parallel port interface on PC has been adapted as an interface to DAQ unit. Nowadays, the conventional parallel port interface is uncommon port. The operation of the system is limited only on a PC completed by conventional parallel port.

The improved DAQ was developed by (Najeb et al., 2005). It employed a popular serial port, USB. The improved DAQ had 12-channels for QT dispersion analysis. The DAQ system consists of an analog multiplexer, a 12-bit ADC and a USB interface module. All units was under control of PIC16F84. The DAQ run on 500 Hz sampling period. The data flow between DAQ and PC was simplex type of communication. It was from DAQ to PC via USB port. The PC on the other side of DAQ received data, demultiplexed and ploted in the form of grpahics. The PC had no functions to control the operation of DAQ system.

A simple example of connecting a PIC16F877 to USB Module could be found on (Axelson, 2005). The proposed method performed a simple echoing data from PC to microcontroller system. The PC send data to microcontroller system and then the microcontroller system receives, increments and sends back to PC. There were no signal processing employed on microcontroller system.

The proposed method implements a PIC16F877A microcontroller completed by ADC and a USB interface module. The amis of selecting the internal ADC on microcontroller is to reduce the problem of signalling on electronic circuit where it could be existed by such as weak soldering and the component orientation.

2. RESEARCH METHODOLOGY

The research was conducted by designing and testing the hardware circuit, developing the software on DAQ system and PC and comprehensive testing on hardware and software.

2.1. PIC16F877A

The PIC16F877A-40 is a family of Microchip 8-bit microcontroller. It is able to opeate on a maximum of 20MHz cyrstral (Inc., 2003). In order to provide maximum sampling period to DAQ, a 20MHz crystal is implemented at oscillator circuit. Hence, the instruction execution speed is 200 nS (Green, 2008). The exploration of PIC16F877A microcontroller includes the ADC, digital I/O, interrupt and look-up table. The microcontroller role is to control the overall data flow of the system including converting the analog input signal, controlling the USB module and simple communication protocol.

2.2. DLP-USB245M-G USB Module

The proposed DAQ system utilizes the USB as a mean of fast serial data transfer and this is made by USB interface chip from FTDI Chip. The FT245BM, a parallel FIFO USB chip, operates as a bidirectional data transfer. The system has 384 byte FIFO Transmit buffer / 128 byte FIFO receive buffer for high data throughput. The interfacing with microcontroller was implemented with a four wire handshaking system. It consists of two wires for control signal and two wires for status signals. The FT245BM manages the enumeration and other bus communications completely in hardware. Hence the controllers require no USB-specific firmware at all, though the designer could use an EEPROM to store the value for some items in the descriptors such as the programmable Vendor ID (VID) and Product ID (PID). The data to be sent of retrieved could be access through eight data pins.

2.3. The System

Figure 1 shows the system interconnection and data flow of the proposed system. The communication between PIC16F877A and USB module employs data bits, status signals and control signals. The status signals involves transmit buffer empty status (TxE) and receiver buffer full status (RxF) while control signals consists of write (WR) and read (RD) control signals. Five analog signals enter the system via analog port of PIC16F877A. The analog signals are digitized by 10-bit A/D module on PIC. Table 1 summarizes the detail pin designation of PIC16F877A in relation with USB Module.

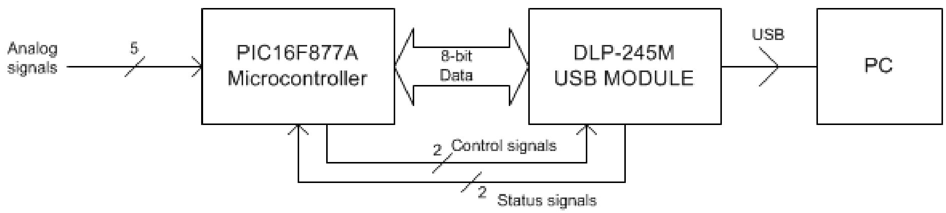

Figure 1 Data acquisition system interconnection

Table 1. PIC16F877A Pin designation in relation with USB module

PIC16F877A		Designation	
Pin	**Function**	**Function**	**Signal**
1	**MCLR/VPP**		
2	**RA0/AN0**	**AN0**	**DAQ CH0**
3	**RA1/AN1**	**AN1**	**DAQ CH1**
4	**RA2/AN2/VREF-/CVREF**	**AN2**	**DAQ CH2**
5	**RA3/AN3/VREF+**	**AN3**	**DAQ CH3**
6	**RA4/T0CK1C1OUT**		
7	**RA5/AN4/SS/C2OUT**		
8	**RE0/RD/AN5**	**RE0**	**WR SIGNAL**
9	**RE1/WR/AN6**	**RE1**	**RD SIGNAL**
10	**RE2/CS/AN7**		
11	**VDD**		
12	**VSS**		
13	**OSC1/CLK1**		
14	**OSC2/CLK0**		

Pin	Function	Function	Signal
15	RC0/T1OSO/T1CK1		
16	RC1/T1OSI/CCP2		
17	RC2/CCP1		
18	RC3/SCK/SCL		
19	RD0/PSP0	RD0	DATA BUS
20	RD1/PSP1	RD1	DATA BUS
21	RD2/PSP2	RD2	DATA BUS
22	RD3/PSP3	RD3	DATA BUS
23	RC4SDI/SDA		
24	RC5/SDO		
25	RC6/TX/CK		
26	RC7/RX/DT		
27	RD4/PSP4	RD4	DATA BUS
28	RD5/PSP5	RD5	DATA BUS
29	RD6/PSP6	RD6	DATA BUS
30	RD7/PSP7	RD7	DATA BUS
31	VSS		
32	VDD		
33	RB0/INT		
34	RB1		
35	RB2		
36	RB3/PGM		
37	RB4	RB4	TXE EMPTY
38	RB5	RB5	RXF FULL
39	RB6		
40	RB7		

Based on Table 1, the bidirectional data bit bus is operated on Port D, while the control signals are on Port E bit 0 and bit 1. The status of USB module is monitored by Port B bit 4 and bit 5. The analog signals are fed on Port A bit 0, 1, 2 and 3.

The sending data can be done when the transmit buffer is not full nor busy storing the last byte written. This is indicated by high logic on TXE status signal. Meanwhile the receiving data can be established RXF FULL status signal is low. When it is low, at least 1 byte is present in the FIFO's receive buffer and is ready to be read.

In order to avoid a trouble exists on data bus, the default direction of data bus is set to be input. This means that the data flow is from the USB Module to microcontroller system. When the data to be sent is available the microcontroller sets the direction of data bus as output port.

The data flow from microcontroller system to USB aims to send the ADC data to PC while the data from USB module given by PC to microcontroller system is to determine the operation of microcontroller system.

2.4. The Microcontroller Programming

The program flow of the microcontroller is illustrated in Figure 2. The flow chart displays the basic data acquisition, conversion and sending processes. The process as illustrated in Figure 2 is operated every sampling period. The internal timer of microcontroller is operated to generate an interrupt at predefined period of time. Once an interrupt generated, the microcontroller executes instructions to do processes in Figure 2. The minimum predefined period of time could be determined by evaluating the time taken by instructions in Figure 2. In other words, the minimum period of time, $t_{S\ min}$, is represented in equation (1).

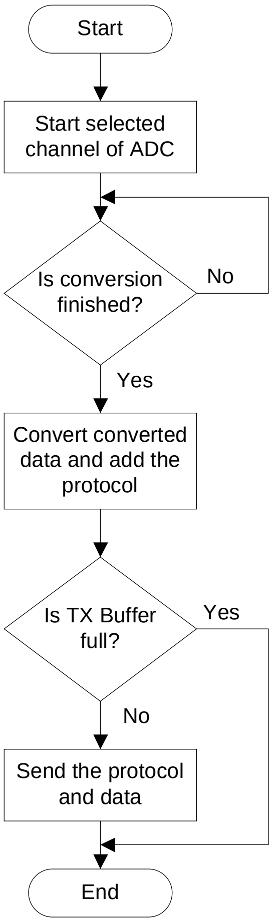

Figure 2 Flow chart of microcontroller firmware

$$t_{S\ min} = t_{ADC} + t_{CONV.} + t_{send} \quad (1)$$

where:

t_{ADC} = the ADC conversion time (mS)
$t_{CONV.}$ = the data conversion time (mS)
t_{send} = the sending procedure time (mS)

The number of ADC channel operated determines the ADC conversion time, t_{ADC}. The maximum number of ADC channel in this proposed method is four. The data conversion and sending procedure time are relatively faster where they are built by instructions.

The converted data given by ADC is in the form of 10-bits. It occupies 2 bytes in memory. The data is then converted into three bytes of ASCII code representing the string. The three bytes of ASCII code represent the low nibble of high byte, high nibble of low byte and low nibble of low byte.

The data identifier is introduced in the communication. Its aim is to indicator between stream of data string. the The identifier implements an asterisk character. It leads the data every data transmission. The PC then inditifies a data based on the ascterisk character.

The transmission of data is initiated by checking the status of transmission buffer. The transmission buffer is a memory on USB module that store data to be sent. If the buffer is not full then the microcontroller write the 4 bytes of string to USB module. If the buffer is full, then the microcontroller does nothing.

2.5. PC Programming

The developed program running on PC is developed in Borland Delphi environment on a Windows XP platform. Figure 3 illustrates the simplified flowchart for the program running on PC. It starts from receiving to storing the data into variable.

The data are displayed graphically on the screen and are updated every 100 mS. The update period does not follow the proces in Figure 3. It relies on the timer. The timer component specifies this update period. The selection of the update period is set based on the user preference The faster the update period the smoother the

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display on the screen. The program also provides a saving menu to save the received raw data for the further purpose.

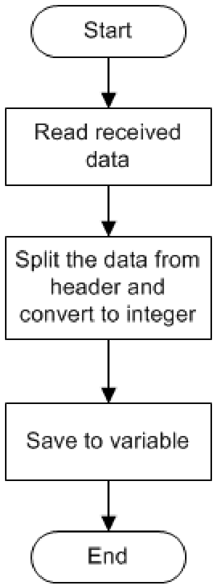

Figure 3 Flowchart of PC program displaying the data

3. RESULTS AND DISCUSSION

The module and components are easly found in the market. The total cost for DLP-USB245M, 40-pin PIC system minimum and PIC16F877A is approximately US$52.09. The ADC module in the PIC gets the reference voltage of 5 volts. Since the ADC converts the analog signal into 10-bits digital data, the resoluiton provided is 4.88mV. That is the step size of ADC output.

The acquisition system acquires the analog signal on 1mS sampling period. During the testing, the system gets analog signal from signal generator. Figure 4, 5, 6, 7 and 8 show the acquisition results for 10 Hz, 20Hz, 30Hz, 40 Hz and 50 Hz positive cycle of sinusoidal signals respectively. The root mean squared and maximum voltage of the signals are 1.8V and 3.76V respectively. Figure 9 depicts the analog signal acquired when the lead is hanging.

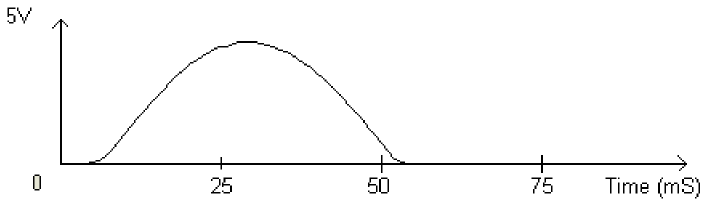

Figure 4 DAQ display on PC for 10Hz signal

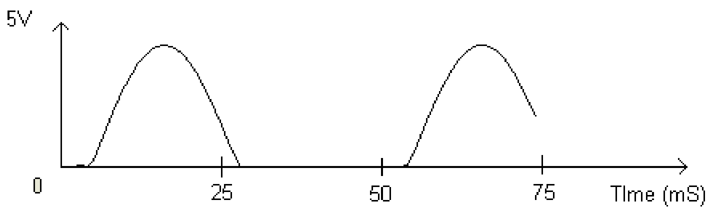

Figure 5 DAQ display on PC for 20Hz signal

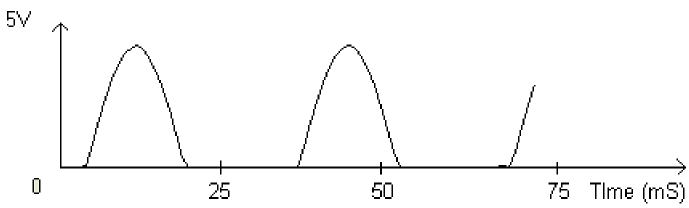

Figure 6 DAQ display on PC for 30Hz signal

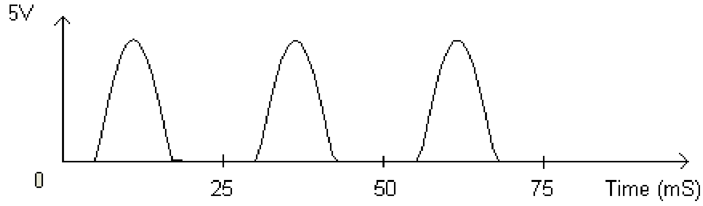

Figure 7 DAQ display on PC for 40Hz signal

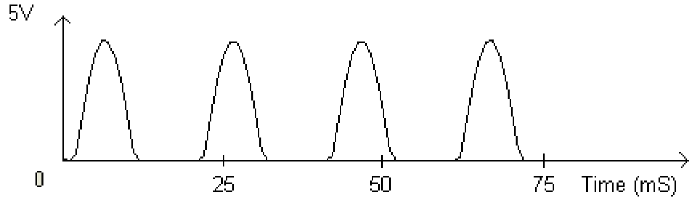

Figure 8 DAQ display on PC for 50Hz signal

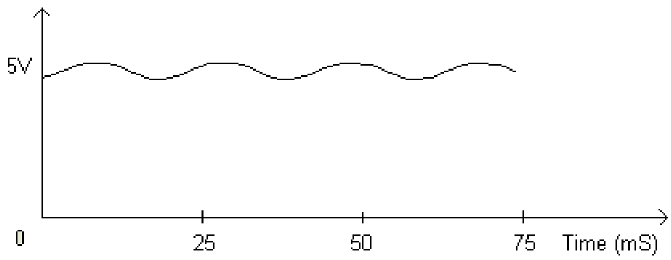

Figure 9 DAQ display on PC for hanging input

4. CONCLUSION

The low cost data acquisiton system has been succesfully developed. The system consists of two main parts, microcontroller system and USB module. The maximum frequency of input signal to be acquired is 500Hz. The method used in this research can be implemented in other activities such as laboratory experiments. By implementing digital signal processing, the system provides the avenues for other research scope.

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