AC 2008-1386: ENHANCING LABORATORY EXPERIENCE TO STUDENTS BY INTRODUCING USB CONNECTIVITY INTO LAB ENVIRONMENT USING FTDI

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Gurinder Singh brings almost a decade of experience in the electronics industry to his position as Senior Field Applications Engineer with Future Technology Devices International Ltd. At FTDI Gurinder is actively involved in embedded USB HOST designs, application notes, technical support on USB devices and HOST controllers, guiding customers to obtain WHQL certifications and USB 2.0 compliance certifications.

Enhancing Laboratory Experience to Students by Introducing USB Connectivity into Lab Environment Using FTDI

Abstract

With over 4 billion devices using Universal Serial Bus (USB) connectivity, USB has become a de-facto standard for connecting peripherals. For a large variety of electronic devices such as cameras, USB flash memory, PC, PDAs, set top boxes, mobile phones and consumer electronics, USB has provided a seamless hot swappable connectivity solution where USB devices can be added or removed while the computer is operating.

This ease of use comes with an elaborate USB specification, device firmware programming, HOST drivers, HOST APIs, standard and custom driver integration, Windows Hardware Quality Labs testing (WHQL) certification, USB compliance testing, and logo certification. For development of any USB based application, a developer must have advanced technical skills in above mentioned USB topics. These are complex topics and a few education/training classes are available. Arizona State University at the Polytechnic campus and Future Technology Devices International (FTDI) Ltd. are partnering to provide venues for both education and training classes for ASU students and FTDI customers respectively. The classes will aim to provide adequate understanding of emerging technologies.

1. Introduction

Traditionally connecting peripherals to PC required cumbersome process of setting jumpers, interrupt requests (IRQs), installing additional hardware and software. USB provides a fast, bi-directional, low-cost and dynamically attachable serial interface. The plug-n-play feature of USB and the support for different communication classes and speeds has led to growing popularity of USB to the extent that today USB is truly a universal connection standard.

The USB protocol is based on *Token, Data* and *Handshake* packets. Before applications can communicate with the device, the host needs to learn about the device and assign a device driver. *Enumeration* is defined as the initial exchange of information that accomplishes this. During the enumeration process, the device moves through *Powered, Default, Address* and *Configured* states as defined by the USB V2.0 specification. Two other USB device states are *Attached* and *Suspend*.

A USB device can have only one device descriptor but multiple configurations. Each configuration may in turn support multiple interfaces. An interface is a related set of endpoints that present a single feature or function of the device to the host. A device endpoint is a uniquely addressable portion of a USB device that is the source or sink of information in a communication flow between the host and device. Endpoint direction refers to the direction of data transfer on the USB. The configuration descriptor specifies values such as the amount of power this particular configuration uses, if the device is self or bus powered and the number of interfaces it has. When a device is enumerated, the host reads the device descriptors and can make a decision of which configuration to enable. With this basic introduction to USB, let's discuss some sample laboratory applications in detail.

The Electronic Systems Department (ESD) at the Polytechnic campus recently restructured their curriculum to provide flexibility for the curriculum to introduce emerging technologies to their students on an ongoing basis by partnering with the industry partners. This paper outlines the laboratory activities as an example to be included into the existing curriculum for the BS degree seeking students in the Electronics Engineering Technology program.

2. Sample Laboratory Applications

In this Section we discuss laboratory experiments that can be easily implemented in an instrumentation USB laboratory using FTDI products. These experiments will provide a student in-depth understanding of various USB concepts.

LAB1 – USB to UART Converter (single-port)

Serial (COM) ports are all but obsolete in today's PCs but legacy embedded applications have been designed with Universal Asynchronous Receiver / Transmitter (UART) interface. A UART provides sampling of a signal to convert a peripheral's serial data stream into the bits and bytes used by the USB bus. The challenge is either to port the embedded application to use USB device controllers or implement an external bridge that translates from USB to RS-232 or TTL level signals with flexibility of selection of RS-232 parameters. FT232R device from FTDI provides this TTL Level protocol translation in a single chip solution.

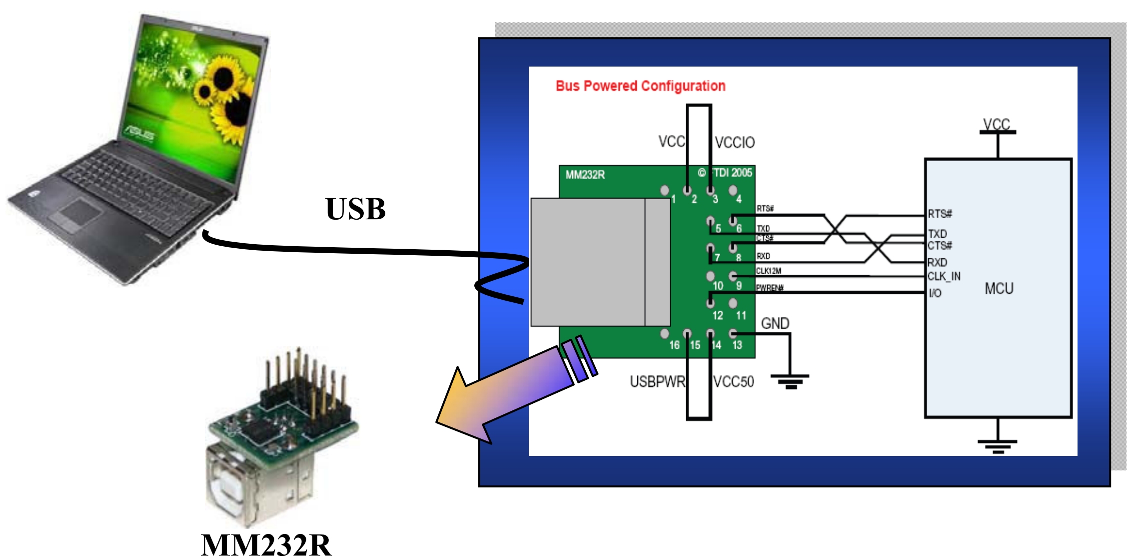


Figure 1 USB – Serial Port interface for Personal Computers using MM232R

The MM232R is a mini development module for the FT232RQ IC device and provides USB - Serial UART interface in an extremely small form factor (See Figure 1 USB – Serial Port interface for Personal Computers using MM232R). It is ideal for new development purposes, and also for adding a USB interface to existing product designs. In this lab experiment students will build a USB to UART converter using FTDI's MM232R module.

Lab Implementation using MM232R: Figure 1 USB – Serial Port interface for Personal Computers using MM232R illustrates MM232R demo in a typical USB bus powered design configuration. This is done by connecting pin 15 (USBPWR) to pin 14 (VCC50). Pin 3 (VCCIO), the supply to the FT232RQ's UART and CBUS IO pins, is connected to pin 2 (VCC). This will make the UART and CBUS IO pins operate at 5V levels.

Figure 1 USB – Serial Port interface for Personal Computers using MM232R also illustrates interfacing the MM232R module to a microcontroller (MCU) UART interface. The lab exercise will involve installation of FTDI's Virtual COM port drivers, carry out the baud rate and handshake signal settings on PC from device manager, establishing a communication link with MCU using HyperTerminal application and finally implementing read and write data operations on target MCU. The students will use USB sniffer to monitor the enumeration process of MM232R and UART data on the USB bus to gain understanding of USB concepts. At the end of this LAB students will gain knowledge on the following important features of USB-UART implementation in an embedded instrumentation design:

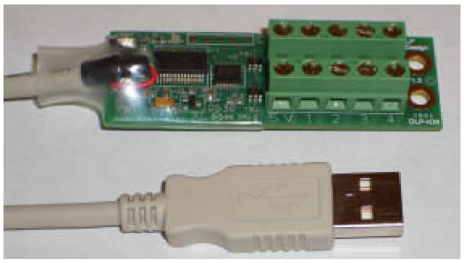
- Single chip USB to asynchronous serial data transfer interface.
- Support for bus powered, self powered, and high-power bus powered USB configurations.
- Integrated 3.3V level converter for USB I/O
- Using FTDI's VCP drivers for COM port emulation
- Using a USB sniffer for reading the USB packets
- Learn USB troubleshooting techniques for diagnosing hardware or software issues

Project Idea - Design a self powered USB – Serial adapter operating at 1.8V TTL signals. This is typically used in battery powered data loggers used in instrumentation and data analysis.

LAB 2 - USB-based 8-channel Data Acquisition Module (DLP-IO8-G)

Data Acquisition is a critical and important part of any instrumentation application. Often engineers need open loop instrumentation controls based on measured voltage levels, temperatures levels etc. or closed loop to control the process through digital I/O interfaces.

FTDI's DLP-IO8 (see Figure 2 DLP - IO8 Figure 3 Screenshot of FLP - IO8 application) provides eight I/O channels that can be independently configured for digital output, digital input, analog input, or temperature modes via simple single-byte commands. This gives the user flexibility to use same hardware for multiple applications. The mode of each I/O is automatically changed with a channel control command. For example, if an I/O is set to Digital Output – High and then the Digital Input Mode is selected, the I/O is first changed to Input Mode and then the high/low state is read and returned to the host.



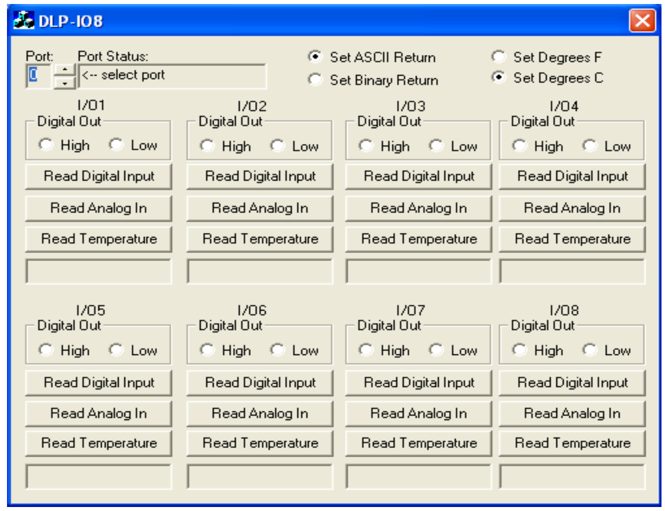


Figure 2 DLP - IO8

Figure 3 Screenshot of FLP - IO8 application

Lab Implementation: The intended purpose of this lab exercise is to analyze and understand control and monitor digital I/O ports in an automation process, monitor analog ports with a USB interface, implement a USB based temperature monitor/record control in an instrumentation application and learn to optimize hardware and control the hardware operation through firmware controls. Students will be able to experiment with DLP-IO8 after connecting the module to the PC and installing relevant drives. The PC application that comes with the DLP-IO8 can be used to understand the operation of the hardware through a Graphical User Interface (See Figure 2 DLP - IO8 Figure 3 Screenshot of FLP - IO8 application) that features the control of analog port, digital port and temperature acquisition. The GUI issues single-byte channel control commands shown in Table 1. After students get familiar with the commands and drivers used in the above application, they can be encouraged to write their own custom GUI application in programming language of their choice.

Table 1 Single Byte Channel 1 Commands

ASCII	Hex Value	Description	Return/Comments
1	0x31	Dig Out - High	Nothing returned
Q	0x51	Dig Out - Low	Nothing returned
A	0x41	Digital input	Return 0 or 1
Z	0x5A	Analog in	Return measured voltage
9	0x39	Temperature	Return current temperature

The temperature data acquisition lab can be set-up by interfacing up to eight DS18B20 digital temperature sensors connected to the DLP-IO8 module for logging the temperature data. Two pairs of wires in the Cat 5 cable are required for the connection. The first pair is for Power (5V) and Ground, and the second pair is designated as Data and Ground. Figure 3.1 shows an example of this connection using I/O Channel 1.

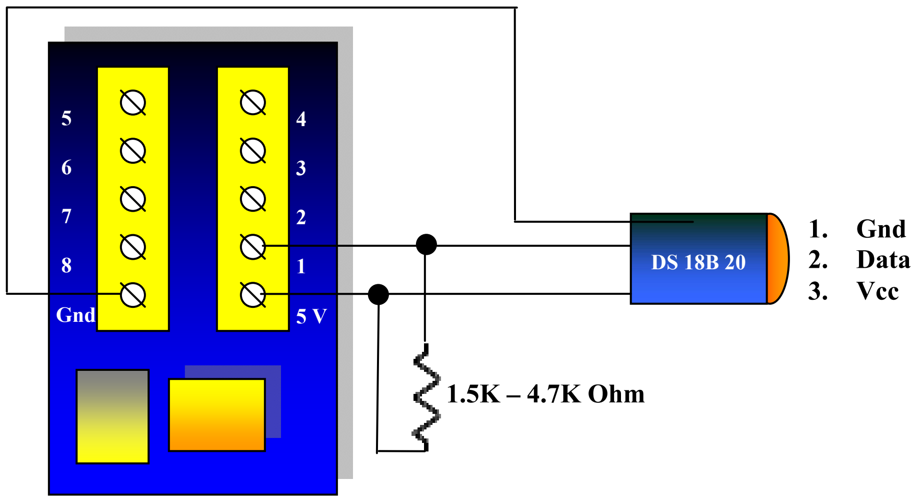


Figure 3.1 Temperature Sensor Interface

At the end of the lab students will be able to add following features to their instrumentation applications

1. Control and monitor digital I/O ports in an automation process
2. Monitor analog ports with a USB interface
3. Implement a USB based temperature monitor/record control in an instrumentation application
4. How to optimize hardware and control the hardware operation through firmware controls

Projects Idea - Implement digital voltmeter, industrial digital I/O control, closed loop FAN control based on temperature sensor readings

LAB 3 - USB Tilt Sensor/Accelerometer/Vibration Analysis (DLP-TILT)

Real time applications like tilt sensor, accelerometer, and vibration analysis are not new in instrumentation field but implementing these applications using USB interface is challenging as the PC application needs to be synchronized with embedded applications.

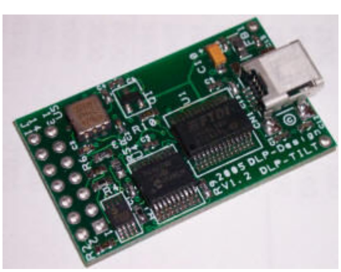


Figure 4 FTDI's DLP-TILT Evaluation Board

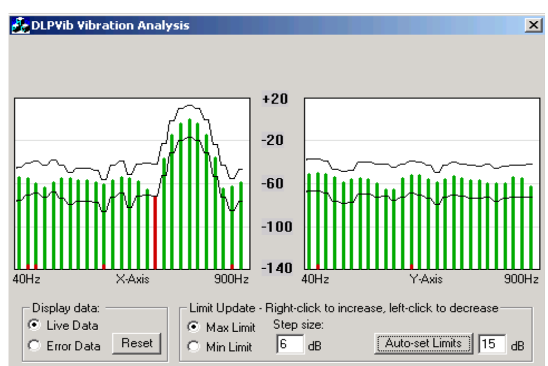


Figure 5 Screenshot of DLPVIB.EXE application

The DLP-TILT module (see Figure 4) incorporates the FT232RL device (USB to UART) while providing following primary instrumentation functions –

1. **Vibration analysis** - 2-axis, 2g accelerometer that can measure frequencies up to 3000 Hz. Two of the analog channels in the microcontroller are dedicated to the on-board accelerometer.
2. **Tilt Sensing** - Accelerometer can measure tilt up to approximately ±60 degrees. The position is reported as an 8-bit or 10-bit integer with the center position reporting the half-scale value of 128 (8-bit) from the A/D converter in the microcontroller.
3. **AC Signal Analysis** - Voltage data can be sampled at rates ranging from 100 samples per second to 6000 samples per second, thereby enabling AC analysis of audio frequencies up to 3KHz. Data received by the PC can be analyzed for frequency content using an FFT-based Windows application.

Lab implementation

The intended purpose of this lab exercise is to analyze and understand implementation of USB based vibration analyzer, tilt sensing devices, and implement real time AC signal analyzers as required in instrumentation applications. Students can experiment with DLP-TILT module by connecting to host machine and installing appropriate drivers. Initialization of DLP-TILT module can be done by sending character ‘P’ on the serial port communication using hyper terminal application. DLP-TILT module responds with character ‘Q’ indication the module is set up and ready to be used for the enlisted applications

1. **DLPVIB.EXE:** This program monitors both channels of the accelerometer and graphically displays frequency and amplitude data proportional to the vibration (See Figure 5 for screenshot of DLPVIB.EXE application).
2. **DLPTILT.EXE -** This program demonstrates tilt feature of the accelerometer and presents the acquired voltages from each of the seven analog inputs (See Figure 6).

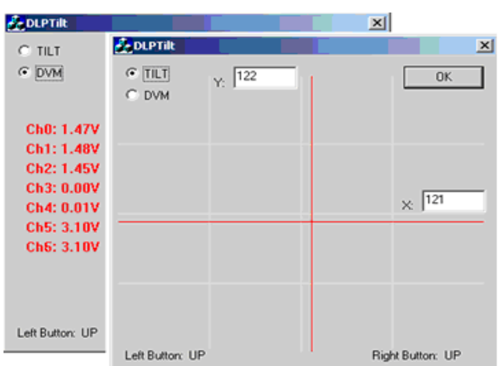


Figure 6 Screenshot of DLPTILT.EXE

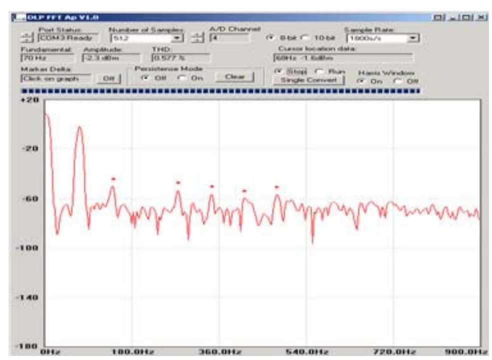


Figure 7 Screenshot of ACQFFT.EXE application

3. **ACQFFT.EXE -** This program acquires AC signal data from any of the seven analog inputs, calculates and displays the FFT of the signal and provides some basic analysis. (See .EXE Figure 7 for screenshot of this application).

At the end of this lab students will be able to implement USB based vibration analyzer, tilt sensing devices, and implement real time AC signal analyzers as required in instrumentation applications.

Lab 4: USB-MP3 player using Vinculum VNC1L (VMUSIC2)

The VMusic2 (see Figure 8) is ideal for adding MP3 playback from USB flash drive to a number of devices, including: home entertainment, in-car audio systems, tourism guides, interactive advertisements, kids learning products, toys and message system in instrumentations applications, and other appliances requiring audio playback capability.

Figure 8 VNC1L VMUSIC2 Module

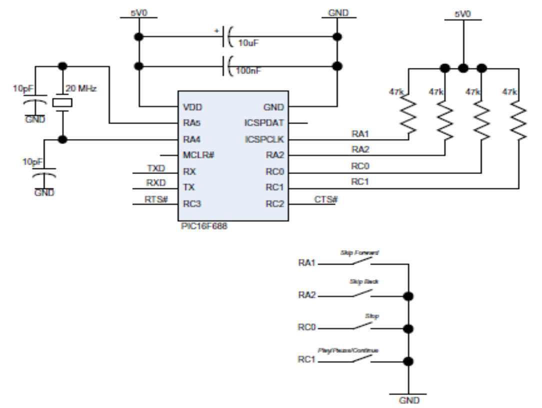


Figure 9 Schematic for PIC-VMUSIC2 interface

Lab implementation - By interfacing with a PIC microcontroller and a few other components, the VMusic2 module can be used to playback audio files stored on a USB flash disk.
Figure 9 shows the schematic of this application. Four push buttons are connected to the inputs on the
PIC micro to provide control features like play, pause, continue, stop, skip forward, skip back, volume up and volume down. The Microchip PIC code is written to pass the standard FTDI VDAP music playback commands. The TXD, RXD, RTS and CTS signals are interfaced with VMusic2 module.

At the end of this lab students will be able to implement an MP3 player based on the FTDI VNC1L-1A USB host controller. They will also learn how to implement VDAP music commands in a PC based application or controlling the MP3 player through embedded microcontroller such as PIC16F688.

3. Summary

In this paper, we have introduced USB concepts and discussed how USB education/training can be part of University's BS degree curriculum and also serve as training material for FTDI customers. We have discussed laboratory set-up and several experiments using FTDI products. In particular, we have discussed implementation of a USB-RS232 converter, a USB device based Data logger, MP3 player, 8 Port I/O, and a sensor interface. The selection of experiments outlined in this paper has many facets that are beneficial to the ASU students and FTDI customers at the same time. ASU students are exposed to the emerging technologies while being in school and will be motivated to engage in these endeavors because the applications are real world applications that they use almost on a daily basis. FTDI customers are the first one to learn these new products and stay ahead of the learning curve compared to their competitors. The two-way partnership with the University and Industry is a win-win situation for the both partners. The real beneficiaries of this effort are students who will have an opportunity to be educated with the latest technology in the classroom and well prepared to enter into the industry after graduation and become a productive employee to the industry partner right from the start of their career.

4. References

1. Universal Serial Bus 2.0 Specification http://www.usb.org
2. FT2xx Datasheets http://www.ftdichip.com/Documents/DataSheets.htm
3. FTDI's DIP development modules http://www.ftdichip.com/Products/EvaluationKits/DIPModules.htm
4. FTDI's Vinculum datasheet http://www.vinculum.com/documents/datasheets/DS_VNC1L-1A.pdf
5. FTDI's Evaluation kits for data acquisition http://www.ftdichip.com/Products/EvaluationKits/DAQ.htm