Introduction to Embedded USB Development

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USB History

• Version 1.0 (January 1996)
  – low and full speed
• Version 1.1 (September 1998)
  – added interrupt OUT transfers
• Version 2.0 (April 2000)
  – added high speed option
• Various ECNs
  – defined new mini-B connector
  – etc.
OS Support for USB

• Windows
  – Windows 95 OEM SR2 (Aug 1996 - limited and buggy)
  – Windows 98 (Jun 1998), 98SE (May 1999), ME (Sep 2000)
  – Windows XP (Oct 2001)

• Linux
  – Kernel 2.4.0 (Jan 2001) and greater

• MacOS
  – Mac OS 8.1 (Jan 1998) and greater
USB Bus Speeds

• Low speed
  – 1.5 Mbits/sec bus speed
  – 800 bytes/sec max data throughput
  – relaxed electrical specifications
    • low cost
    • flexible cables, e.g. mice

• Full speed
  – 12 Mbits/sec bus speed
  – 1.2 Mbytes/sec max data throughput

• High speed
  – 480 Mbits/sec bus speed
  – 53 Mbytes/sec max data throughput
USB Attributes

• Universal – one interface for many types of devices
• Easy to connect
  – External connectors: no need to open enclosure
  – Automatic configuration
  – Inexpensive cables (5 meters max), reliable connectors
  – Hot pluggable
• No user settings
• Efficient resource usage (only the host controller consumes I/O ports, IRQs, memory)
• Supplies power to devices (+5V @ 500 mA)
USB Development Challenges

• Protocol complexity
  – USB 2.0 Specification is 650 pages
  – EHCI Specification is 155 pages
  – HID Device Class Definition is 97 pages

• Operating system support
  – Try to use an existing class driver
  – Try to adapt an existing driver

• Host controller to device
  – Not peer-to-peer -- partial solution is “USB On-The-Go” specification released in 2001
  – No broadcasts as in Ethernet or Firewire (IEEE-1394)

• Fee for Vendor ID (VID)
VID/PID

• Every device must have a unique VID/PID
• Vendor ID - 16 bits
  – e.g. 0x04d8 = Microchip
• Product ID - 16 bits
  – e.g. 0x000a = Microchip RS-232 CDC example
• VID/PID in firmware must match VID/PID in driver, e.g. in Windows .INF file
VID/PID Alternatives

• Purchase a VID from usb.org
  – $1500 (~$0.04/PID)

• Purchase a small quantity of PIDs within someone else’s VID, e.g. Wouter van Ooijen
  – http://www.voti.nl/shop
    • 10/€20 (about $33 with S/H)
    • 100/€90 (about $116 with S/H)

• Free for lab use (“may not leave your desk”) from Wouter van Ooijen
  – VID 5824 = 0x16c0
  – PID 1000-1009 = 0x03e8 through 0x03f1
USB Terminology

- **Host**
  - USB host controller
  - USB root hub
- **Hub**
  - contains 1 upstream connector and 1 or more downstream ports
  - repeats USB traffic in both directions
  - manages power
  - sends and responds to status and control messages
  - can cascade up to 5 hubs in series
  - up to 127 peripherals and hubs including root hub
  - a USB 2.0 hub MUST support low, full, and high speed devices
USB Terminology (cont.)

• Function
  – a device that provides a capability to the host
    • mouse
    • speakers
    • storage
    – a single physical device can contain more than 1 function

• Device
  – a function or hub
  – communicates with host

• Compound Device
  – contains a hub and 1 or more functions

• Port
  – each connector represents a USB port
Common USB Connectors

Type A  Type B  Mini-A  Mini-B
USB Host Controller Types

• **OHCI - Open Host Controller Interface**
  – Developed by Compaq, Microsoft, and National Semiconductor
  – Adopted as version 1.0 and 1.1 (low and full speed) standard by USB-IF
  – Simple SW, more complex HW
  – All chipsets except Intel and VIA

• **UHCI - Universal Host Controller Interface**
  – Competing specification developed by Intel, requires licensing fee
  – Simple HW, more complex SW
  – Intel and VIA chipsets only

• **EHCI - Enhanced Host Controller Interface**
  – High speed USB only
Multiple Host Controllers on Motherboard

Select “Devices by connection” view

OHCI
OHCI
OHCI
EHCI
Types of USB Transfers

• Control
  – Identification and configuration
  – The only required type, the only defined functions

• Bulk
  – Printer, scanner, disk

• Interrupt
  – Mouse, keyboard

• Isochronous
  – Streaming audio or video
USB Project Alternatives

• RS-232/USB Converter
  – FTDI Chip FT232BM USB UART
  – Usually no changes required to application SW

• IEEE-1284 (Parallel)/USB Converter
  – USB controller with 17 or more I/O bits required
    • 8 bidirectional data pins
    • 5 status outputs
    • 4 control inputs
  – Prolific Technology PL-2305
  – Application SW changes required
USB Controllers that Interface to External CPUs

- Agere Systems USS-820D
- FTDI Chip FT232BM (serial), FT245BM (parallel)
  - No USB-specific firmware required
  - Can use FTDI Chip’s driver and Vendor ID
- National Semiconductor
- Philips Semiconductor
- PLX Technology
USB Controllers with Embedded CPU

- Cypress EZ-USB (originally Anchor Chips)
  - Full or full/high speed, can load firmware from host or ROM
- Cypress enCoRe II
  - Inexpensive low speed controllers
- Freescale MC68HC908JB16
  - Low speed
- Freescale MCF5482 ColdFire
  - 32-bit CPU + full/high speed
- Microchip PIC16C745/765
  - Low speed
- Microchip PIC18F2455/2550/4455/4550
  - Full speed
Why Microchip?

- Chips readily available in small quantities
- Chips reasonably priced in small quantities
- Free or inexpensive development tools
- Full documentation freely available
- Free example code
  - Human Interface Device (HID) firmware
  - Communication Device Class (CDC) firmware
  - Mass Storage Class firmware
  - Bootloader firmware
  - Custom driver
Microchip Full Speed USB

• PIC18F2455
  – 24 KB Flash, 24 I/O, 10 channel 10-bit ADC
• PIC18F2550
  – 32 KB Flash, 24 I/O, 10 channel 10-bit ADC
• PIC18F4455
  – 24 KB Flash, 35 I/O, 13 channel 10-bit ADC
• PIC18F4550
  – 32 KB Flash, 35 I/O, 13 channel 10-bit ADC
• All have 2 KB RAM, 256 bytes EEPROM
Microchip PICDEM FS-USB

- Inexpensive ($59.99) development board
  - PIC18F4550 full speed USB microcontroller, 20 MHz crystal
  - RS-232 serial port connector/interface (for demonstration of migration from legacy applications)
  - connection to the MPLAB® ICD 2 In Circuit Debugger
  - voltage regulation, with the ability to switch from external power supply to USB bus supply
  - expansion connector, compatible with the PICtail™ daughter boards standard
  - temperature sensor TC77 (connected to the SPI bus)
  - potentiometer (connected to RA0 input) for A/D conversion demonstrations
  - 2 LEDs for status display, 2 LEDs for power indication
  - 2 input switches
  - reset button
  - bootloader firmware, demo applications
PICDEM FS-USB
Microchip Development SW

• MPLAB IDE
  – Free
  – MPASM Assembler, MPLINK Linker, MPLIB Librarian
  – MPLAB SIM Simulator

• MPLAB C18 Compiler
  – Free Student/Demo Edition (some optimizations disabled after 60 days)
  – $495 for full version
Microchip Development HW

• PICkit 2 ICSP (In-circuit Serial Programmer)
  – $49.99 Starter kit
    • ICSP
    • Low pin count demo board

• MPLAB ICD 2 (In-circuit Debugger)
  – $160
  – Real-time “background” debugger
    • 1 stack level
    • 12 bytes (0x3f4-0x3fff) file registers
    • 64 bytes (0x7dc0-0x7dff) memory
  – Programmer
PICkit 2 Starter Kit
ICD 2 In-Circuit Debugger
USB Firmware Development

• With Microchip bootloader installed, embedded system can self-host over USB
  – Upload/download code
  – Program Flash memory

• Use ICD 2 to program/debug in-circuit

• Use PICKit 2 to program via ICSP (In-Circuit Serial Programming)
USB Driver Development

• Use an existing driver
  – Microchip-furnished driver
  – Standard USB class driver

• Create a driver from scratch
  – Not a trivial task
  – Use Windows Driver Development Kit (DDK)
  – Or use a commercial driver toolkit (expensive!)
USB Application Development

• Windows
  – http://libusb-win32.sourceforge.net/
  – http://www.steelbrothers.ch/jusb/

• Mac OS

• Linux
  – http://www.linux-usb.org/
  – http://libusb.sourceforge.net/
  – http://jusb.sourceforge.net/
References

• USB Implementers Forum
  – Free download of USB specifications
  – http://www.usb.org

• *USB Complete, 3rd Edition*, Jan Axelsson
  – The best USB book
  – http://www.Lvr.com

• Microchip USB Controller Resources
  – http://www.microchip.com/usb