USB/PCI

E155
Sources

• Harris and Harris 2\textsuperscript{nd} Ed. Chapter 8
• http://en.wikipedia.org/wiki/Universal_Serial_Bus
PC I/O

- Memory
- Disks/storage
- Networking
- Internal Expansion
- External Devices
PC Motherboard

Figure 8.70 Gigabyte GA-H55M-S2V Motherboard

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Peripheral Trends

• Fewer parallel ports
  – Parallel wires prevent high speeds
  – Transmission line problems
  – Reflections, different flight times

• More serial ports
  – High speed
  – Properly terminate transmission lines
  – Less noise
  – Faster than 10Gb/s over copper
PC Peripherals

• Expansion cards
  – Open case
  – Set jumpers
  – Manually install driver

• RS-232 device
  – Get the right cable
  – Configure baud rate, data, parity and stop bits
USB

• Universal Serial Bus
• Simplifies peripherals
  – Standard cables
  – Standard software configuration
• Billions of USB peripherals sold each year
USB 1.0

• 1996
• 4 wires
  – 5 V
  – GND
  – Differential pair for data
• Impossible to plug in wrong
• 12 Mb/s
• Up to 500 mA for the device
USB 2.0

• 2000
• Faster differential wires
• 480 Mb/s
• Fast enough for more devices
  – Webcams
  – External hard disks
  – Flash memory sticks (replaced floppy disks)
USB 3.0

- 2008
- Even faster wires
- More wires
- 5 Gb/s
- Same shape connector
USB Speeds

• LS: Low Speed (1.5 Mb/s)
• FS: Full Speed (12 Mb/s)
• HS: High Speed (480 Mb/s)
• SS: Super Speed (5 Gb/s)
USB Connector

# USB 3.0

<table>
<thead>
<tr>
<th>Pin</th>
<th>Color</th>
<th>Signal (B in parenthesis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Red</td>
<td>VBUS</td>
</tr>
<tr>
<td>2</td>
<td>White</td>
<td>D-</td>
</tr>
<tr>
<td>3</td>
<td>Green</td>
<td>D+</td>
</tr>
<tr>
<td>4</td>
<td>Black</td>
<td>GND</td>
</tr>
<tr>
<td>5</td>
<td>Blue</td>
<td>StdA_SSRX- (StdB_SSTX-)</td>
</tr>
<tr>
<td>6</td>
<td>Yellow</td>
<td>StdA_SSRX+ (StdB_SSTX+)</td>
</tr>
<tr>
<td>7</td>
<td>Shield</td>
<td>GND_DRAIN</td>
</tr>
<tr>
<td>8</td>
<td>Purple</td>
<td>StdA_SSTX- (StdB_SSRX-)</td>
</tr>
<tr>
<td>9</td>
<td>Orange</td>
<td>StdA_SSTX+ (StdB_SSRX+)</td>
</tr>
</tbody>
</table>
USB Device Classes

• Notify the host
• Provides portability
• Devices from different manufacturers
• Host selects the appropriate driver
# USB Device Classes

<table>
<thead>
<tr>
<th>Class</th>
<th>Usage</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00</td>
<td>Device</td>
<td>Unspecified</td>
<td>Interface descriptors determine drivers</td>
</tr>
<tr>
<td>0x01</td>
<td>Interface</td>
<td>Audio</td>
<td>Speaker, Microphone, MIDI</td>
</tr>
<tr>
<td>0x02</td>
<td>Both</td>
<td>Communications</td>
<td>Modem, Ethernet adapter, Wi-Fi adapter</td>
</tr>
<tr>
<td>0x03</td>
<td>Interface</td>
<td>Human interface (HID)</td>
<td>Keyboard, mouse, joystick</td>
</tr>
<tr>
<td>0x06</td>
<td>Interface</td>
<td>Image</td>
<td>Webcam, scanner</td>
</tr>
<tr>
<td>0x08</td>
<td>Interface</td>
<td>Mass storage</td>
<td>USB flash drive, memory card reader, etc.</td>
</tr>
<tr>
<td>0x09</td>
<td>Device</td>
<td>USB hub</td>
<td>Full bandwidth hub</td>
</tr>
<tr>
<td>0x0D</td>
<td>Interface</td>
<td>Content Security</td>
<td>Fingerprint reader</td>
</tr>
<tr>
<td>0xE0</td>
<td>Interface</td>
<td>Wireless Controller</td>
<td>Bluetooth adapter</td>
</tr>
<tr>
<td>0xFF</td>
<td>Both</td>
<td>Vendor-Specific</td>
<td>Device needs vendor-specific drivers</td>
</tr>
</tbody>
</table>
USB Packets

• Full-bandwidth and low-bandwidth
  – Low value: 0.0 to 0.3 V
  – High value: 2.8 to 3.6 V

• Hi-bandwidth
  – Low value: -10 to 10 mV
  – High value: 360 to 440 mV
USB Packets

• Two differential states: J, K
• NRZI Convention:
  – 0 indicated by switch from J to K or K to J
  – 1 indicated by staying the same
• Extra 0 after six consecutive 1s (bit stuffing)
• Start of Packet: 0000 0001 (KJKJKJKK)
• End of Packet (EOP): 2 bit times of SEO (low) followed by J
USB Packets
USB Packets

• Many different types
• Look them up on your own!
PIC32

• Built in USB controller
• Supports Full Speed (FS) (12 Mbps)
• Drivers can be complicated
• Example in Lab7
• Be sure to do your research
Apple Lightning Connector

- Uses USB 2.0 for signaling
- Proprietary protocols internally
PCI (express)

- Peripheral Component Interconnect
- PCI – older (slower) standard
- PCI express (newer)
  - x16 slot: High performance
  - x1 slot: Low performance
  - x4, x8 slots: In between
- Used for expansion cards
- Serial, USB, network, sound, modem, video
PC Motherboard

Figure 8.70 Gigabyte GA-H55M-S2V Motherboard
PCI

- 1994
- 32-bit parallel bus 33 MHz clock
- 133 MB/s
- 5 V signaling
- 64-bit option (confusingly called PCI-X)
PCIe

- PCI Express
- One or more high-speed serial lanes
- PCIe 3.0 each lane is 8 Gb/s
  - Up to x16 lanes
  - 16 GB/s
- PCIe 4.0 each lane is 16 Gb/s
  - Up to x16
  - 32 GB/s (16 GB/s in each direction)
What is a lane?

• Two differential signal pairs
  – Send, receive
  – 4 wires (signal traces)
• Functions as a byte stream (8-bits)
• PCIe slots from 1-32 lanes
• 16 is the largest in common use
Picture Time

x4
x16
x1
x16
PCI
PCI vs. USB

- Many previously PCI devices moving to USB
- Motherboards build in lots of USB
- PCIe used for graphics cards
- Other high-performance accelerators
  - Intel Xeon Phi
  - Caustic RT Accelerator
  - μMudd32 ?
More information on PCI

Quick SD Card Note

• http://hades.mech.northwestern.edu/index.php/PIC32MX:_Interfacing_to_a_Secure_Digital_(SD)_Flash_Card