

# An Introduction to Universal Serial Bus

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# Overview

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- Introduction
- History
- Hierarchy
- Enumeration
- Demonstration Circuit
- Conclusions
- Questions



# Introduction

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- USB - Universal Serial Bus
- Replaces legacy interfaces - RS232 and Parallel
- Plug-and-play
- Fast, user-friendly (usually)
- Commonly found in printers, scanners, keyboard/mouse, external hard disk, flash drives, digital cameras, webcams ...



# History

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- USB has gone through several revisions
- Initial release USB1.0 in November 1995
- USB1.0 - 1.5Mbps (Low-Speed) and 12Mbps (Full-Speed)
- Re-release USB1.1 in Sept. 1998 - rectify adoption problem
- USB2.0 Released in April 2000
- USB2.0 - 480Mbps(High-Speed) and backward compatible



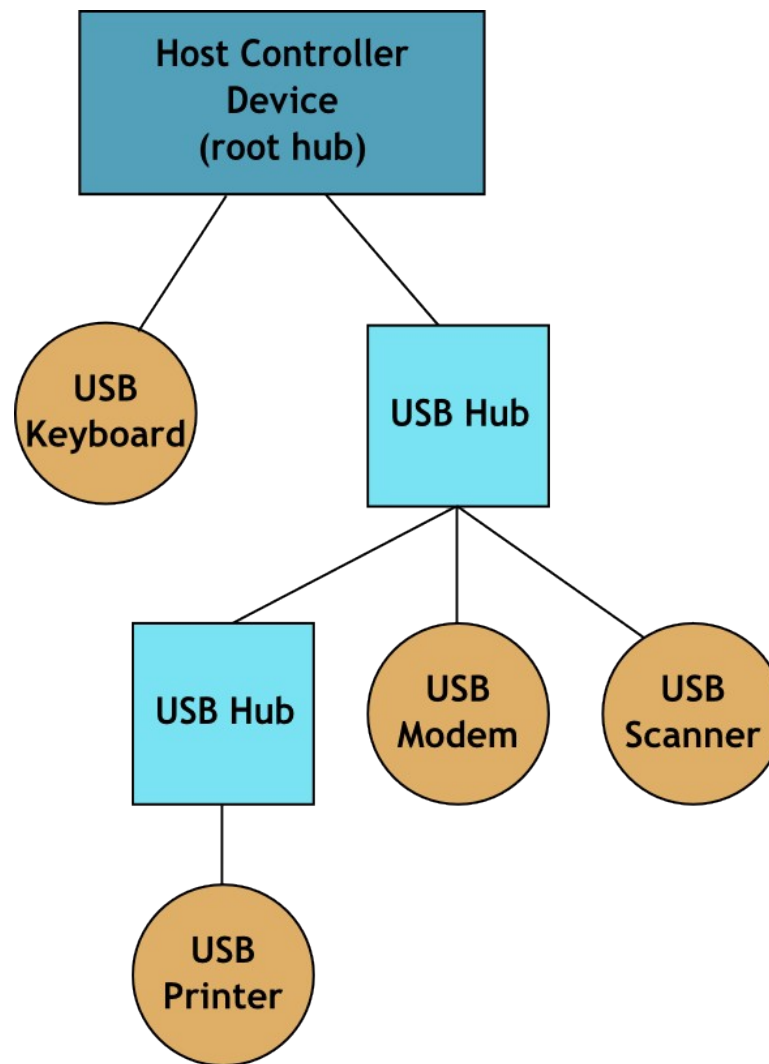
# Why so popular?

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- USB is low cost in comparison to high-speed serial bus technologies like IEEE1394 (FireWire)
  - USB is tiered-star topology, FireWire is peer-to-peer based requiring “smarter” peripherals
  - USB devices cannot initiate communication, FireWire devices can communicate with any node, at any time.
  - USB network has single host, where in FireWire any node can control the network

# Topology of USB

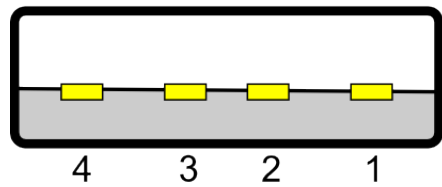
- Tiered-Star Topology
- Hubs used for branching
- 5 tiers of hubs permitted
- 127 devices maximum
- bandwidth is limited and varies with device count



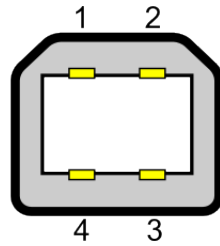
*USB Topology*



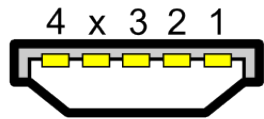
# USB Connector & Cabling



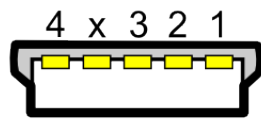
Type A



Type B

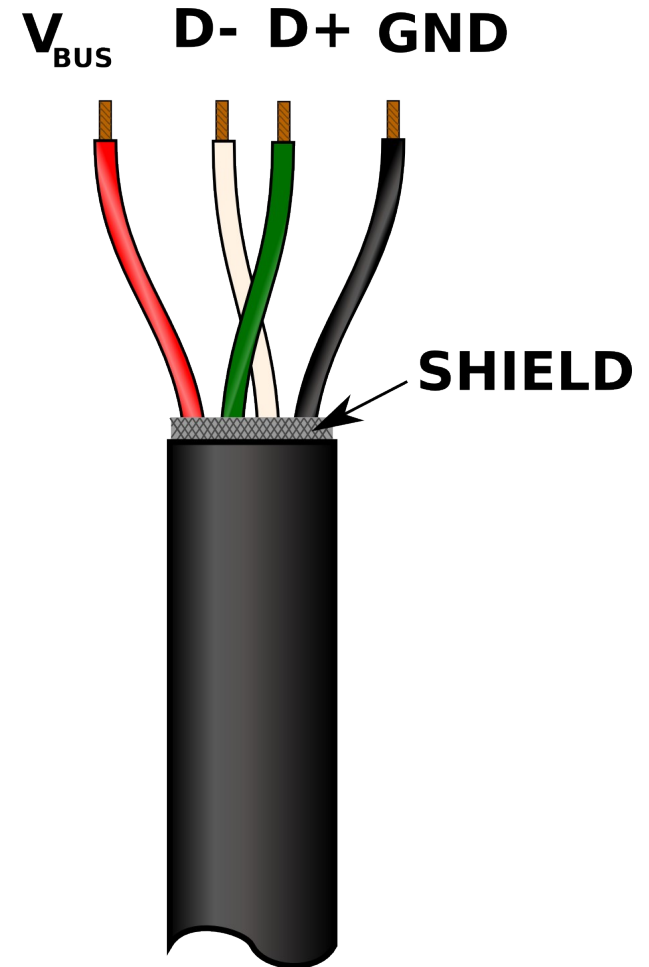


Mini-A



Mini-B

*USB Connectors*



*USB Cable*



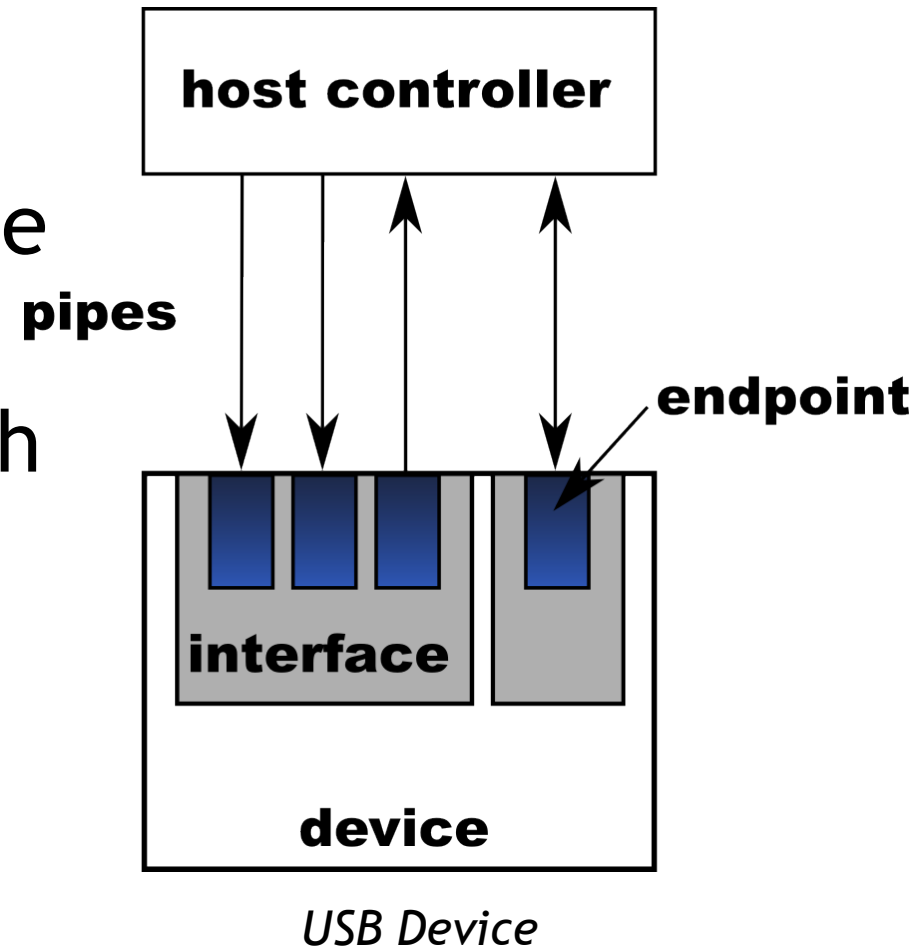
# USB Device Classes

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- Devices can be fully custom requiring a custom driver, or may belong to a device class
- Device classes define behaviour of device so a single device driver can be used for various devices
- Common Device Classes include: Mass Storage Device, Human Interface Device (HID), USB hub and Printer

# USB Device

- Single Physical device may consist of several logical sub-devices
- Interfaces used to separate device functionality
- Drivers exchange data with endpoints over pipes (logical channels)
- Endpoints are uni-directional





# Endpoint Zero (Control Endpoint)

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- Endpoint Zero required by all devices for standard requests (device descriptors)
- During enumeration, device identifies itself with the host OS by set of standard requests over EP0
- Endpoint Zero is only bi-directional endpoint
- Often used for vendor control requests also



# Data Flow Types (Endpoints)

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- **Control** - for enumeration, control and status where data is non-periodic (**device control**)
- **Bulk** - large payloads, guaranteed data with built-in error checking and hardware retries (**flash drive, external hard drive**)
- **Interrupt** - when data is small and infrequent with bounded service period (**keyboards/mice**)
- **Isochronous** - periodic data where data rate is superseded integrity (**webcam**)



# Designing a USB Device

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- Application speed requirements
  - Full Speed 480Mbps
  - High Speed 12Mbps
  - Low Speed 1.5Mbps
- Find a suitable USB peripheral controller
- Determine the interface(s) and endpoints of the device
- Write firmware, driver and software!



# Cypress EZ-USB FX2 Controller

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- Integrated high-speed USB microcontroller
  - Single Chip USB2.0 transceiver, serial interface engine and enhanced 8051 core
- Firmware can be loaded from external EEPROM or over USB
- Two USART controllers, an I2C controller
- Integrated 4kB FIFO for endpoints (slave mode or general purpose interface)



# Cypress EZ-USB GPIF

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- GPIF provides internal master for internal endpoint FIFOs.
- User defined waveform descriptors control GPIF state machine
- Can be used for interface between ASICs, DSPs, or even more complex interfaces such as ATAPI for PATA hard drive interface.



# USB Driver Development

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- Device driver required to interact with device
- Drivers are OS specific and HW dependent
- **Kernel Drivers**
  - Requires proficient programming or may crash system by overwriting memroy
- **User-Space / User-Mode Drivers**
  - More stable than kernel drivers, cannot crash kernel.
  - Performance overhead when transitioning between user and kernel space



# libUSB

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- Collection of User-Space routines for manipulating USB devices without need for kernel driver
- Available for Linux, Windows, Mac OSX and FreeBSD (and others).
- Supporting functions for
  - finding devices on in a USB system
  - selecting and claiming interfaces
  - control, bulk and interrupt transfers
  - no isochronous endpoint support



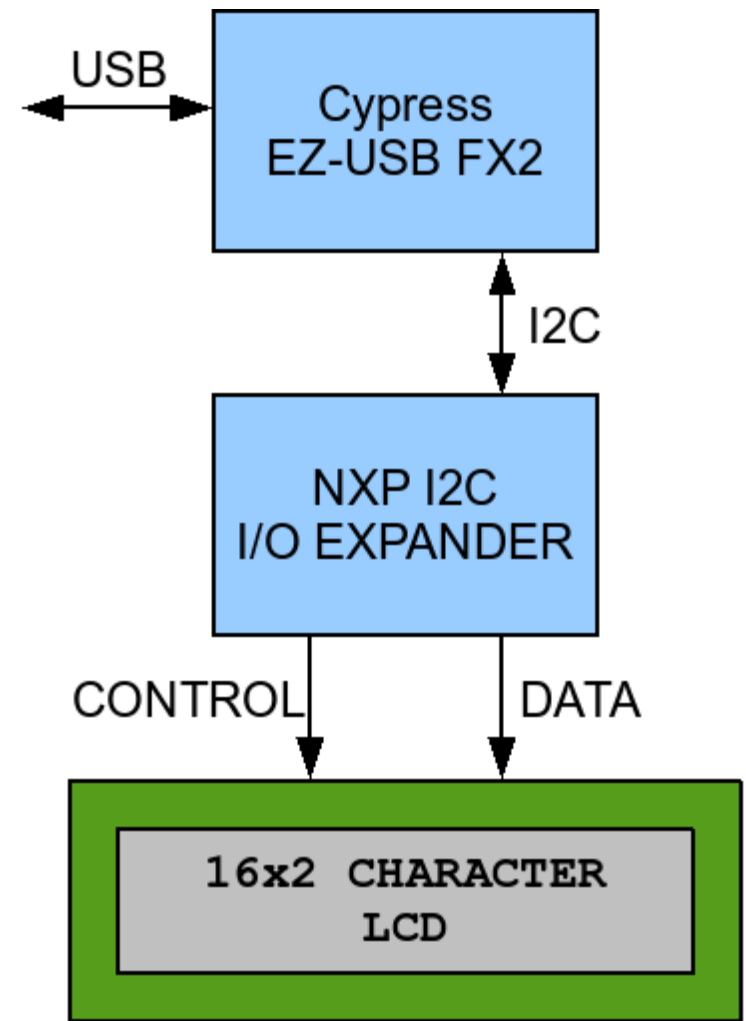
# libUSB

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- Allows a designer a relatively easy API to use when interacting with devices
- Not as fast as a kernel-mode driver but much easier to develop
- Wrappers have been created for Python, Perl and Java

# Demo Circuit - USBLCD

- Set of Vendor Specific Requests to control character LCD
- Data is sent to default control endpoint. No additional endpoints used.
- I/O Expander board used to control inputs of LCD operating at 5V



*USBLCD Block Diagram*



# Demo Circuit - User-Mode Driver

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- Written in Python using pyUSB wrapper for libusb

```
class DeviceDescriptor(object) :
    def __init__(self, vendor_id, product_id, interface_id) :
        self.vendor_id = vendor_id
        self.product_id = product_id
        self.interface_id = interface_id

    def getDevice(self) :
        buses = usb.busses()
        for bus in buses :
            for device in bus.devices :
                if device.idVendor == self.vendor_id :
                    if device.idProduct == self.product_id :
                        return device
        return None
```

*Python Code Snippet for finding a USB Device*



# Demo Circuit - User-Mode Driver

```
class devUSBLCD(object):
    USBLCD_VID = 0xabcd
    USBLCD_PID = 0x0501
    USBLCD_IFID = 0
    ...
    def __init__(self):
        self.device_descriptor = DeviceDescriptor (self.USBLCD_VID,
                                                    self.USBLCD_PID,
                                                    self.USBLCD_IFID)

        self.device = self.device_descriptor.getDevice()
        self.handle = None

    def open(self):
        self.device = self.device_descriptor.getDevice()
        self.handle = self.device.open()
        self.handle.claimInterface(self.device_descriptor.interface_id)
    ...
    def setLCDL1(self, msg):
        ret = self.handle.controlMsg(self.VENDOR_REQUEST_OUT,
                                     self.VRQ_SET_LCD_L1,
                                     msg,
                                     value=0,
                                     index=0,
                                     timeout=100)
    ...
```

*Python Code Snippet for finding a USB Device*



# Questions?

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