USB Basics (By SE Nickols , DMR LLC)

The Universal Serial Bus is a "bit serial" communications protocol. The USB protocol specifies both the software and hardware components involved in allowing hardware, such as a camera, to communicate with a host computer.

A host computer will store, in a library, the USB devices supported. In other words, a user can have multiple USB devices supported (i.e. a mouse and camera). Upon opening an application, and plugging in a USB device into a USB port, the computer will select a class device driver. The User can interact with the device, such as a camera, by using a "GUI" (graphical user interface) to open and interact with the selected device.

The USB host software is layered. The layering supports many classes of devices. A class is a grouping of devices with similar characteristics. A generic device driver can control devices with similar characteristics. An example of device classes is video devices, mass storage devices, "human interface devices" (i.e. mouse), and communications devices.

Referring to figure 1, the USB protocol layer starts with the user interface. In the case of a "human interface device" an application and the graphical user interface are tied together (as in the case of a mouse). A mouse or keyboard will utilize the interrupt handling capability of the USB protocol. A "mouse" will use a different device driver and buffering mechanism than a video camera. A mouse is sending data about position intermittently, thus the use of interrupts.

The host computer "transacts" with the "class" of device selected. There are 4 USB Transactions types as illustrated in table 2.
A video camera with USB, can stream video data continuously. A host computer will utilize an Isochronous transaction to handle data from the video camera. In the mouse example above, the computer uses an interrupt transaction.

The host computer selects a transaction during the process of **enumeration**. Enumeration starts once the computer detects a USB device. Upon detection, the computer will automatically decide the USB bus speed, High Speed or Low Speed, the class of device, and the device driver to use. See figure 4.

From the physical interface standpoint, a pull up resistor, on the remote device side, tells the host the bus speed. The host detects the pull up on either signal line D+ or D-. A pull up resistor on D- indicates a Low Speed (1.5mhz) device. A pull up on D+ indicates a High Speed (12mhz) device.

Enumeration steps:

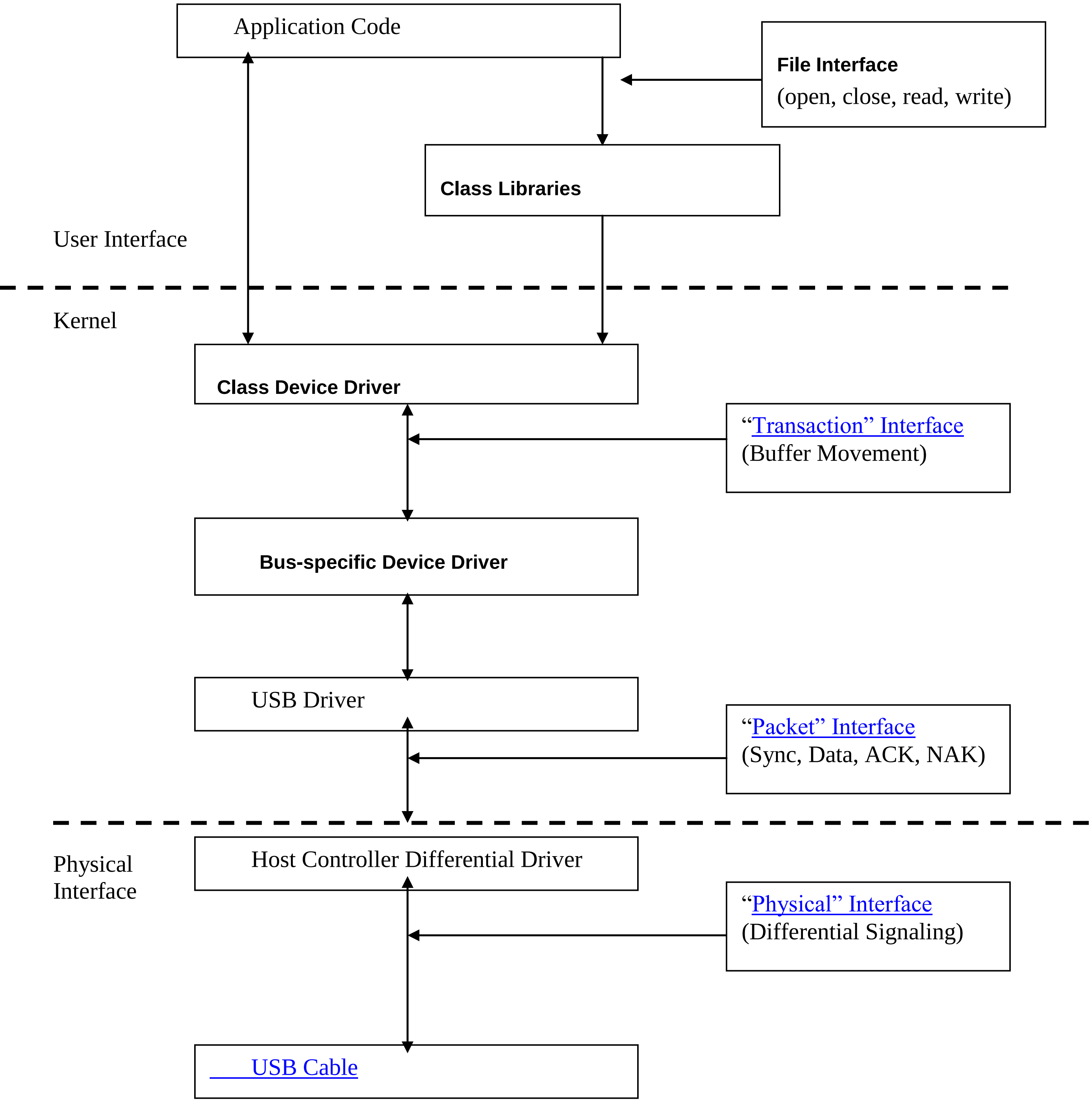
1. Host discovers newly attached device.
2. Host clears this status.
3. Host sends a reset command (lasts 10 milliseconds).
4. Host discovers reset is complete.
5. Host sends a command to remote device to determine its description.
6. The host sets an address for the device.
7. Host sends a command to remote device to collect info about the device.
8. Host selects a device driver.
9. The device is configured and ready to use.

All host to remote and remote to host communications occur in a structured (defined) sequence of packets. Packets are driven on the USB two-wire bus Differentially. See figure 2. Communications occur in a half duplex mode.

USB data packets consist of three pieces: a start, some information, and an end. The start of a packet is the SYNC sequence. The SYNC sequence is 8 bits long. The receiver uses this sequence to tune receive clock. At the 8th bit time, the data (information) sequence begins. The data sequence can be from one byte (PID only) to 1025 (PID plus data). See figure 3.

At the beginning of the information portion of the packet, is the Packet ID. The Packet ID is formed of 4 bits and the complement of these 4 bits. This allows for error checking. There are 16 PID types as shown below. See table 1.

USB protocol layer. Figure 1



Differential Signaling

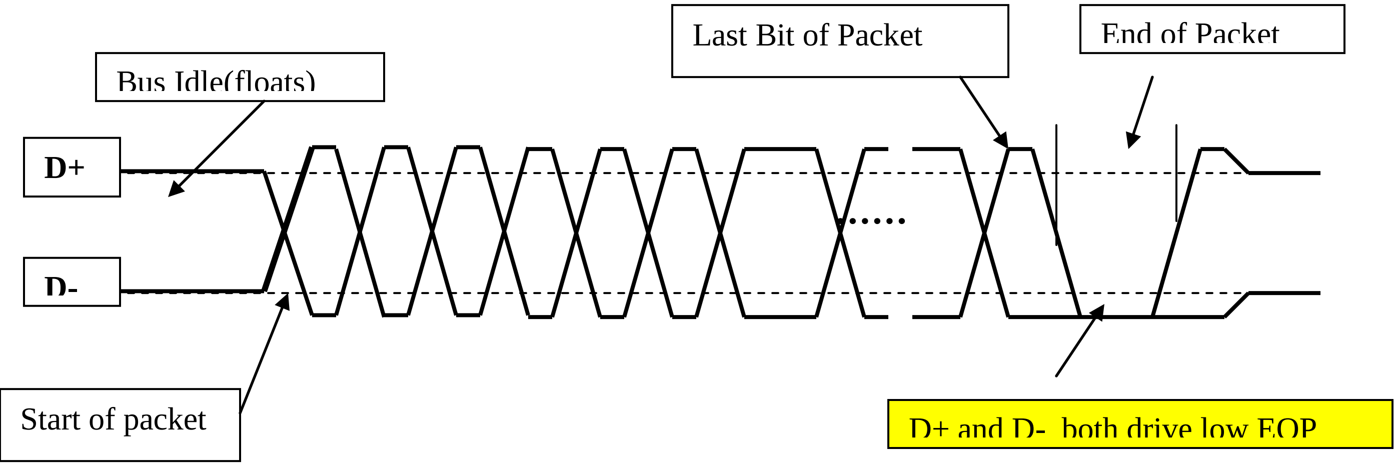


Figure 2

Fundamental Packet

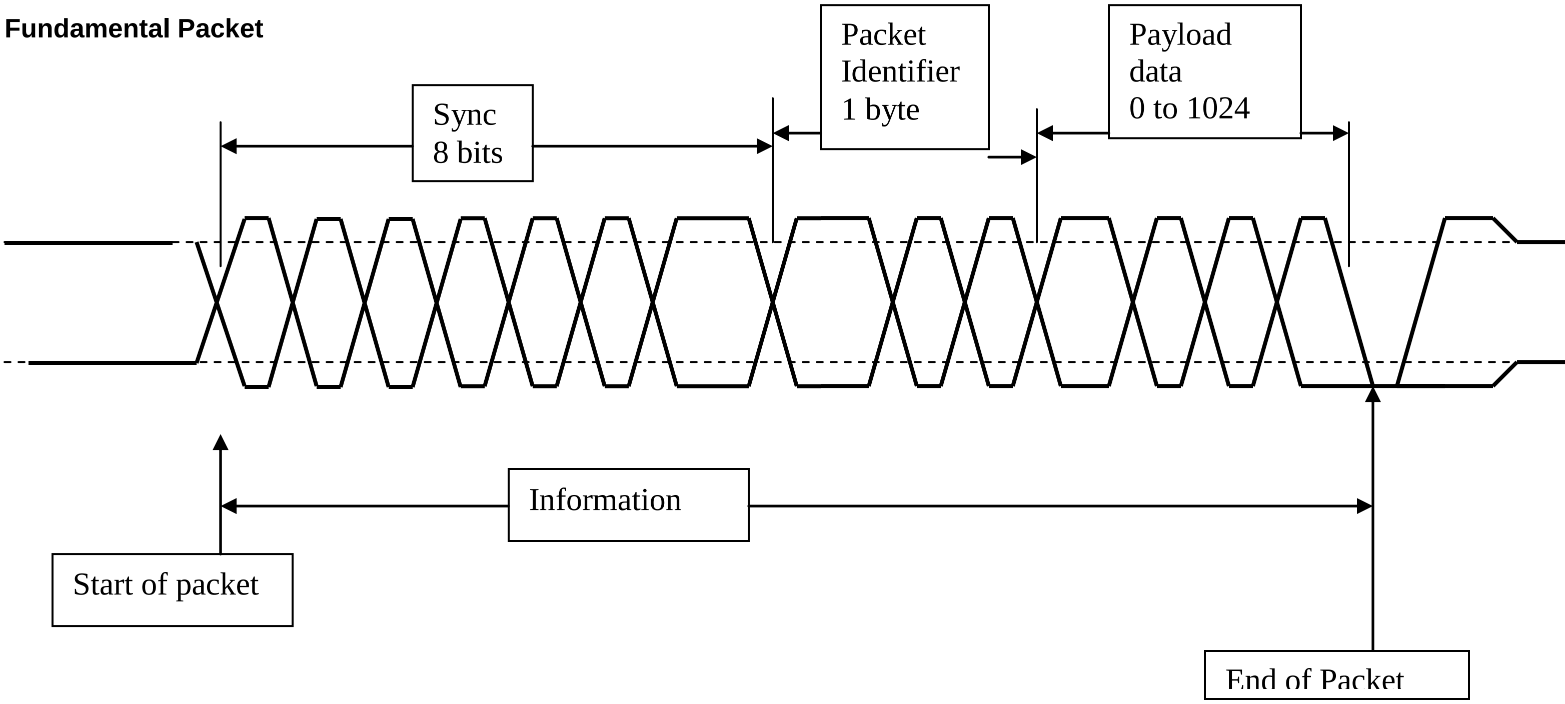
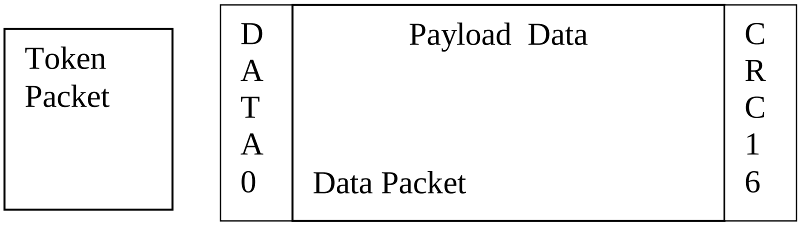


Figure 3



Isochronous Packet.

Table 1

PID Value	Packet Type	Packet Category
0101	START OF FRAME	Token
1101	SETUP	Token
1001	IN	Token
0001	OUT	Token
0011	DATA0	Data
1011	DATA1	Data
0010	ACK	Handshake
1010	NAK	Handshake
1110	STALL	Handshake
1100	PRE	Special
Others	RESERVED	RESERVED

Transaction types.

Table 2

Type	Attributes	Maximum Size	Example
Interrupt	Quality	64 bytes	Mouse, Keyboard
Bulk	Quality	64 bytes	Printer, scanner
Isochronous	Time	1024 bytes	Speakers, Video
Control	Time and Quality	64 bytes	System control

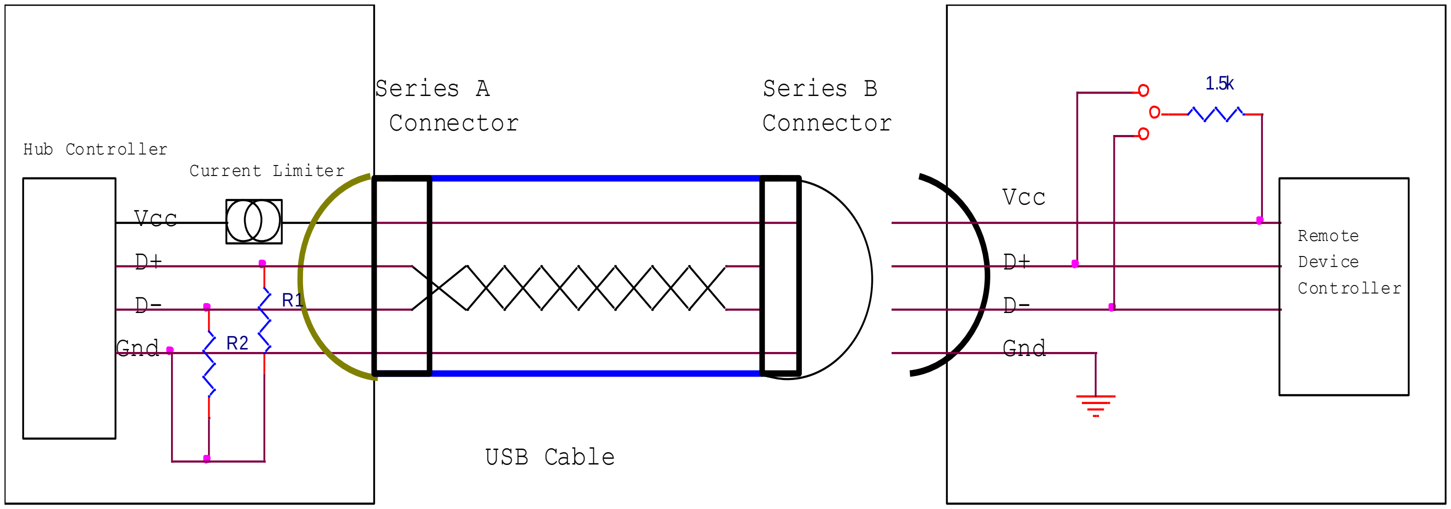

Hub Controller
Current Limiter
Vcc
D+
D-
Gnd
R1
R2
Series A
Connector
Series B
Connector
USB Cable
1.5k
Vcc
D+
D-
Gnd
Remote
Device
Controller

Figure 4