ECE 471 – Embedded Systems
Lecture 19

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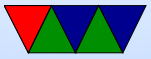
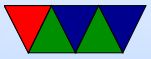
Announcements

- Project ideas!

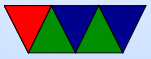


USB Bus

- USB 1.0 – 1996 – Low Speed 1.5Mbit/s (keyboard, etc), Full Speed 12Mbit/s (disk)
- USB 1.1 –
- USB 2.0 – 2000 – High Speed 470MBit/s
- 2-5m cables
- 4 pins. 5V, GND, D+, D-. Differential signalling (subtract). More resistant to noise.

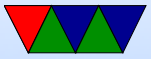


- Micro connectors have extra pin for on-the-go (says if A end or B end gnd vs v+)
- Unit load, 100ma. Can negotiate up to 500ma (more USB 3.0)
- Up to 127 devices (by using hubs)
- Enumeration, vendor and device



USB Bus

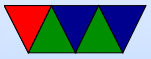
- USB 3.0 – 2008 – SuperSpeed 5GBit/s (though hard to hit that) Full Duplex (earlier half duplex)
- USB 3.1 – 2014 – SuperSpeed+ 10Gbit/s
- Backwards compatible, has 5 extra pins next to standard micro with GND, SSTX+/- and SSRX+/- (full duplex)
- USB-C – 2014
  24-pin: 4 power/ground pairs, two differential non-super-speed pairs, four pairs of high-speed data bus, two



sideband pins, two pins for cable orientation

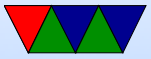
cables can be USB2, USB3, USB3.1, up to 5A(20V=100W) but 3A more common

wrong pullup can cause cable that damages hardware

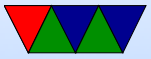


USB Signaling

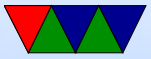
- Differential signalling, twisted pair, 90Ohm impedance
- Low+Full = 0V low, 3.3V high, not terminated
- High = 0V low, 400mV high, terminated with resistor
- SuperSpeed, separate lines, but original lines used to config
- Host, 15k pulldown pulls data lines to 0 (nothing connected, SE0)

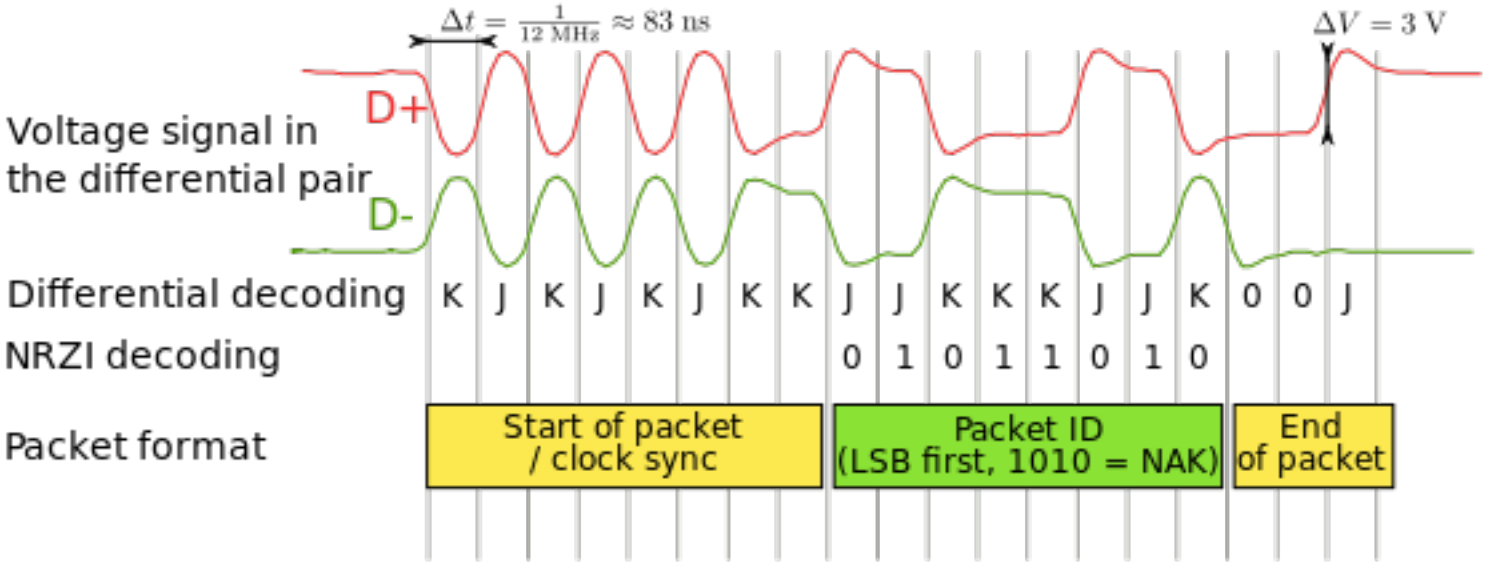


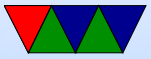
- USB device pulls line high with 1.5k which overpowers pulldown. Full bandwidth D+ high, low bandwidth D- high
- J and K states.
- NRZI line coding – 0 signaled by J to K (switching state). 1 signalled by leaving as is
- Bit stuffing – after six consecutive 1s must include 0
- starts with 8 bit synch – 00000001 which is KJKJKJKK. Data then sent. End marked by 00J.



- Reset by 10ms SE0
- Highspeed uses "chirping" to negotiate speeds, during reset chirps J and K
- SuperSpeed uses 8b/10b encoding (limits bandwidth), CRC, other features
- SuperSpeed+ uses 128b/132b encoding
- Example from Wikipedia CC0:

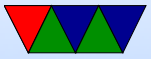



$\Delta t = \frac{1}{12\ \mathrm{MHz}} \approx 83\ \mathrm{ns}$
$\Delta V = 3\ \mathrm{V}$
Voltage signal in the differential pair
D+
D-
Differential decoding
K J K J K J K K J J K K K J J K 0 0 J
NRZI decoding
0 1 0 1 1 0 1 0
Packet format
Start of packet / clock sync
Packet ID (LSB first, 1010 = NAK)
End of packet



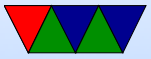
Latency

- For Low and Full shortest transaction time is 1ms. Can this be a problem?



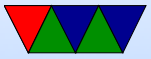
USB Protocol

- Various packets sent
- Checked by CRC



USB Design

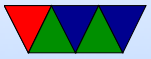
- Each device has endpoint
- isochronous – guaranteed data rate but with some potential data loss (video)
- interrupt – low-latency, like keyboards
- bulk – disk access



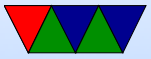
USB Linux

- Linux drivers
  - Device classes – HID, audio, etc. One common driver can handle all devices of a class
  - Specific – device driver is board specific and must have a list of all vendor/device IDs that are supported

- libusb
  Allow direct userspace access to USB interface
  Used by low-level things that might not need driver

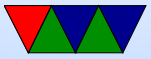


old cameras (not standardized), custom hardware



USB on Rasp-pi

- USB-OTG – on the go. Allows device to act like a host (so can hook up devices as per normal) or as normal USB device. Decides which based on whether A or B cable plugged in, check ID pin (micro/mini have 5th pin)
  The Pi-B does not support running in gadget mode externally (a hub in the way) and the OTG hardware requires more software support than (it is simpler) than regular USB.



- USB 2.0 (sorta). Cannot supply full power (why? Only 1A power supply typical). Also cannot handle high-bandwidth things like audio cards and USB-cameras well.

- USB-host – standard USB port. Cannot provide high current, so use a powered hub if using anything more than keyboard or mouse