

I/O devices



- I/O devices:
 - serial links
 - timers and counters
 - keyboards
 - displays
 - analog I/O

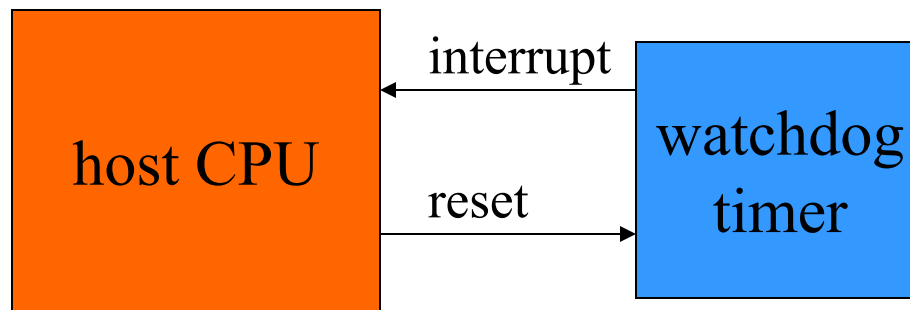
Timers and counters



- Very similar:
 - a **timer** is incremented by a periodic signal;
 - a **counter** is incremented by an asynchronous, occasional signal.
- Rollover causes interrupt.

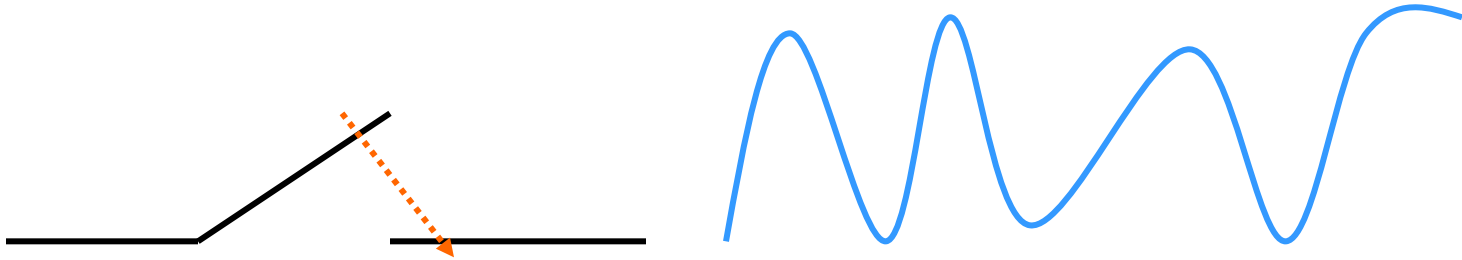
Watchdog timer

- Watchdog timer is periodically reset by system timer.
- If watchdog is not reset, it generates an interrupt to reset the host.



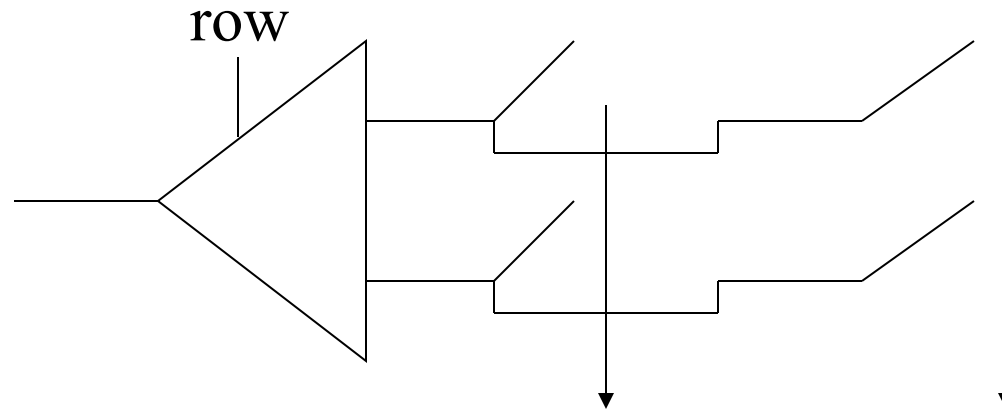
Switch debouncing

- A switch must be debounced to multiple contacts caused by eliminate mechanical bouncing:



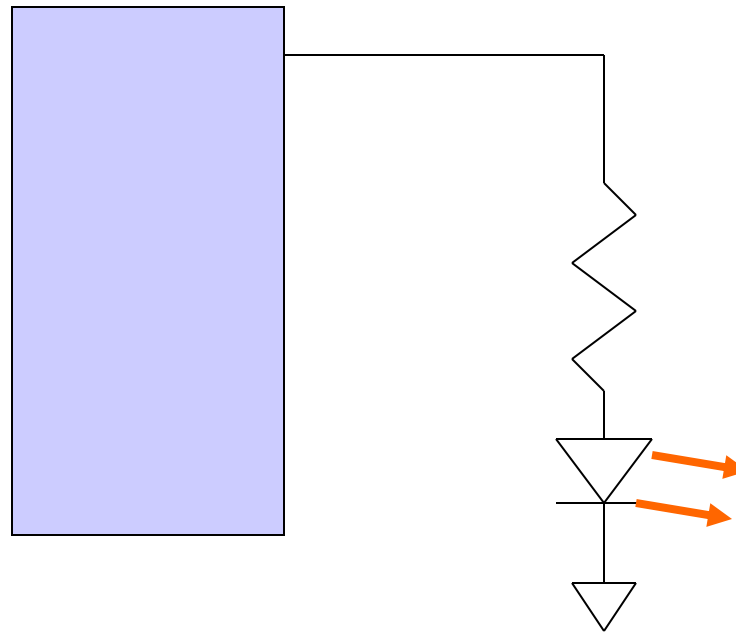
Encoded keyboard

- An array of switches is read by an encoder.
- **N-key rollover** remembers multiple key depressions.



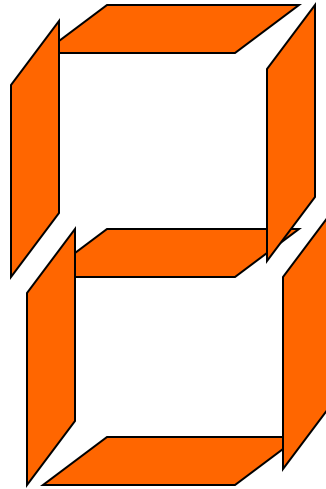
LED

- Must use resistor to limit current:



7-segment LCD display

- May use parallel or multiplexed input.



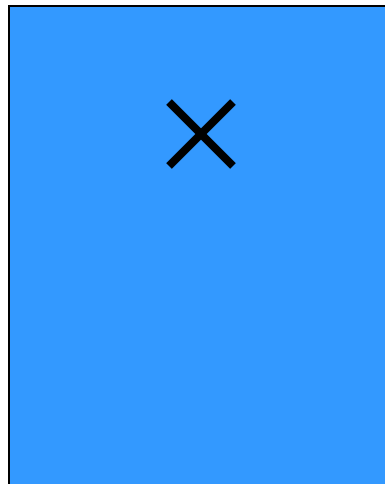
Types of high-resolution display



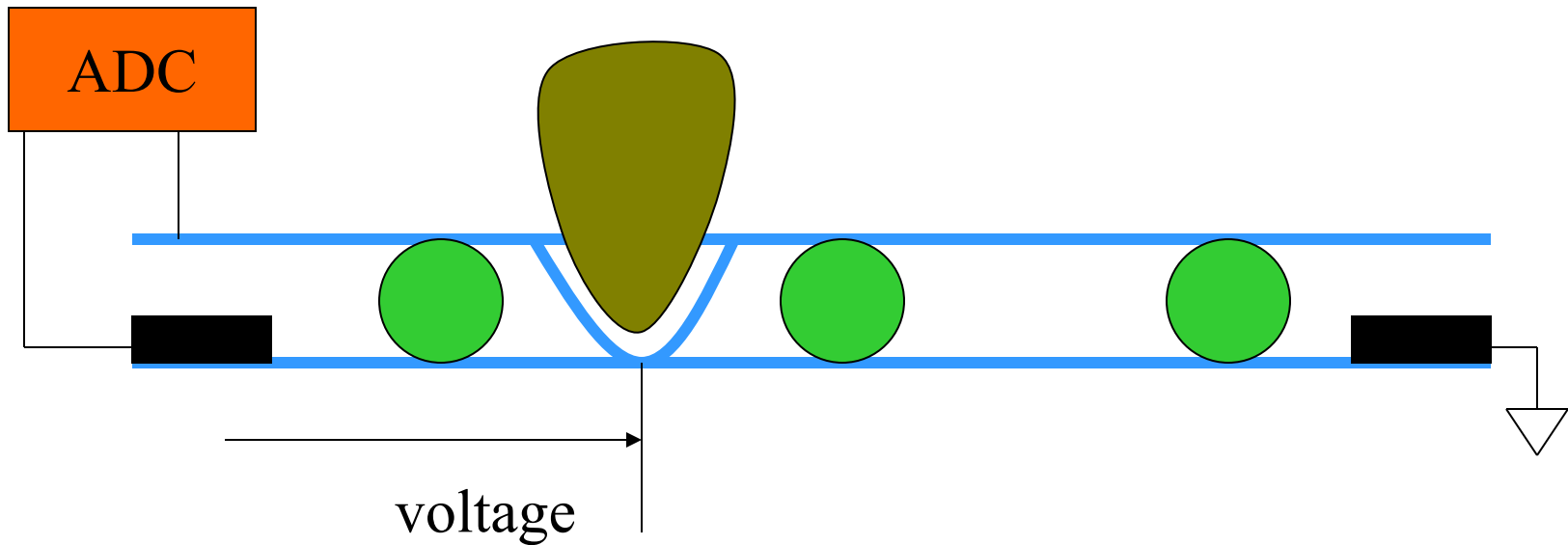
- Cathode ray tube (CRT)
- Liquid crystal display (LCD)
- Plasma, etc.

Touchscreen

- Includes input and output device.
- Input device is a two-dimensional voltmeter:

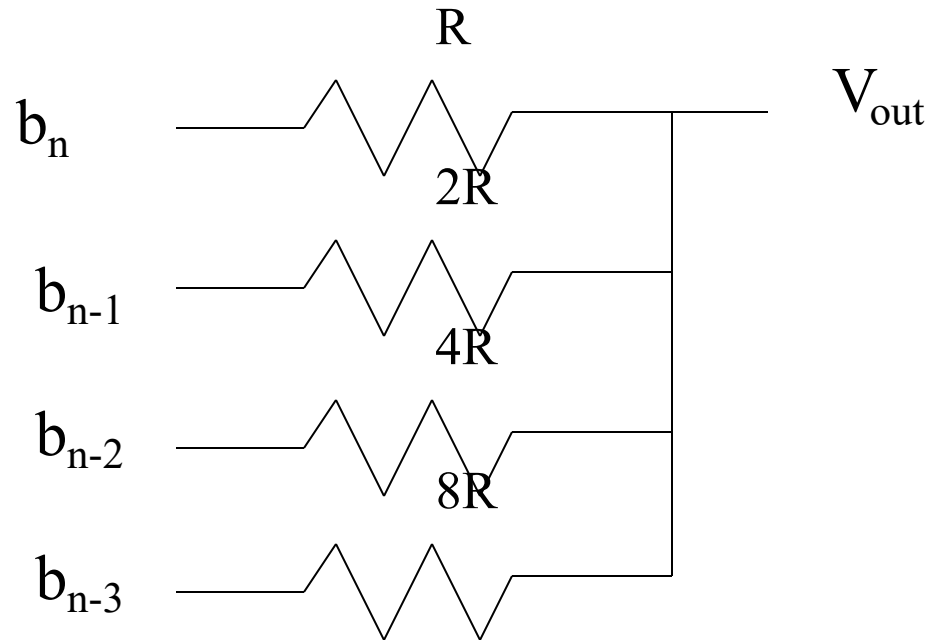


Touchscreen position sensing



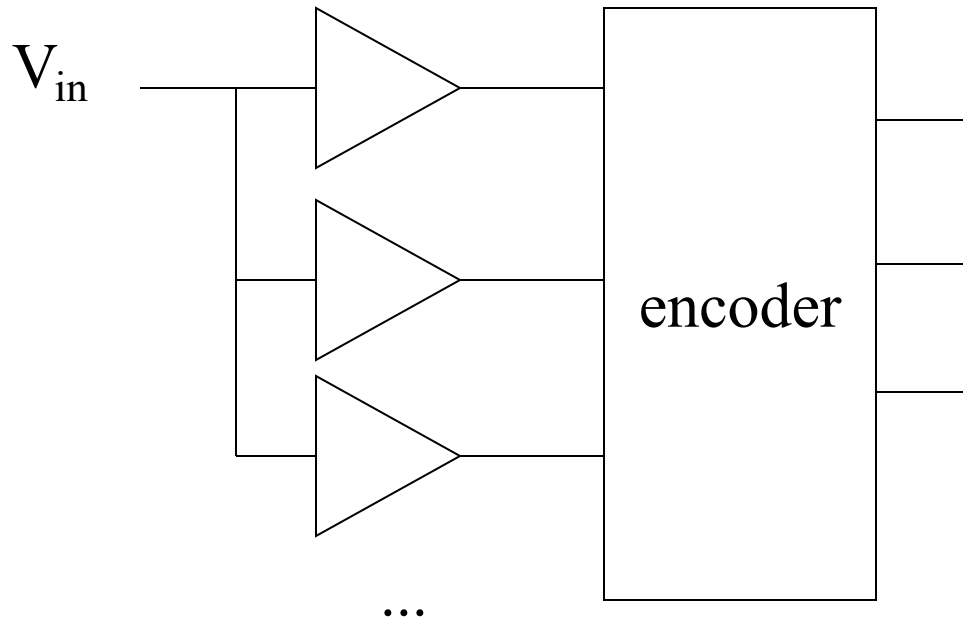
Digital-to-analog conversion

- Use resistor tree:



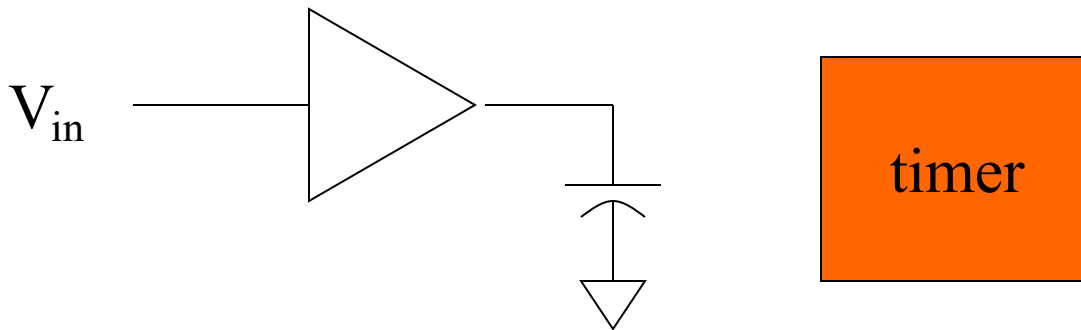
Flash A/D conversion

- N-bit result requires 2^n comparators:



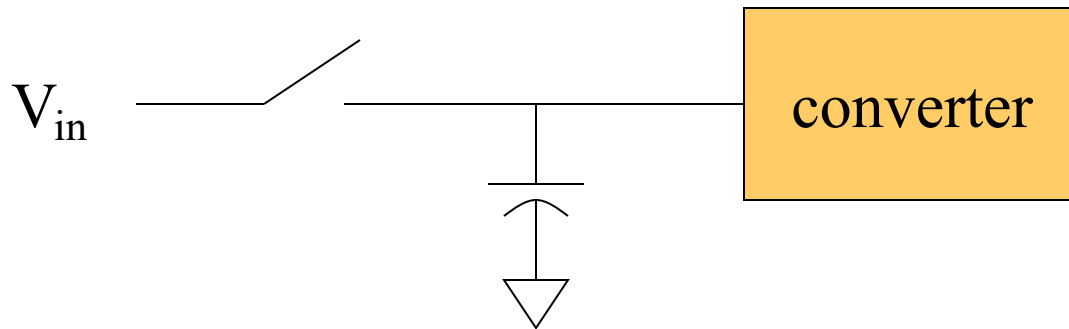
Dual-slope conversion

- Use counter to time required to charge/discharge capacitor.
- Charging, then discharging eliminates non-linearities.



Sample-and-hold

- Required in any A/D:



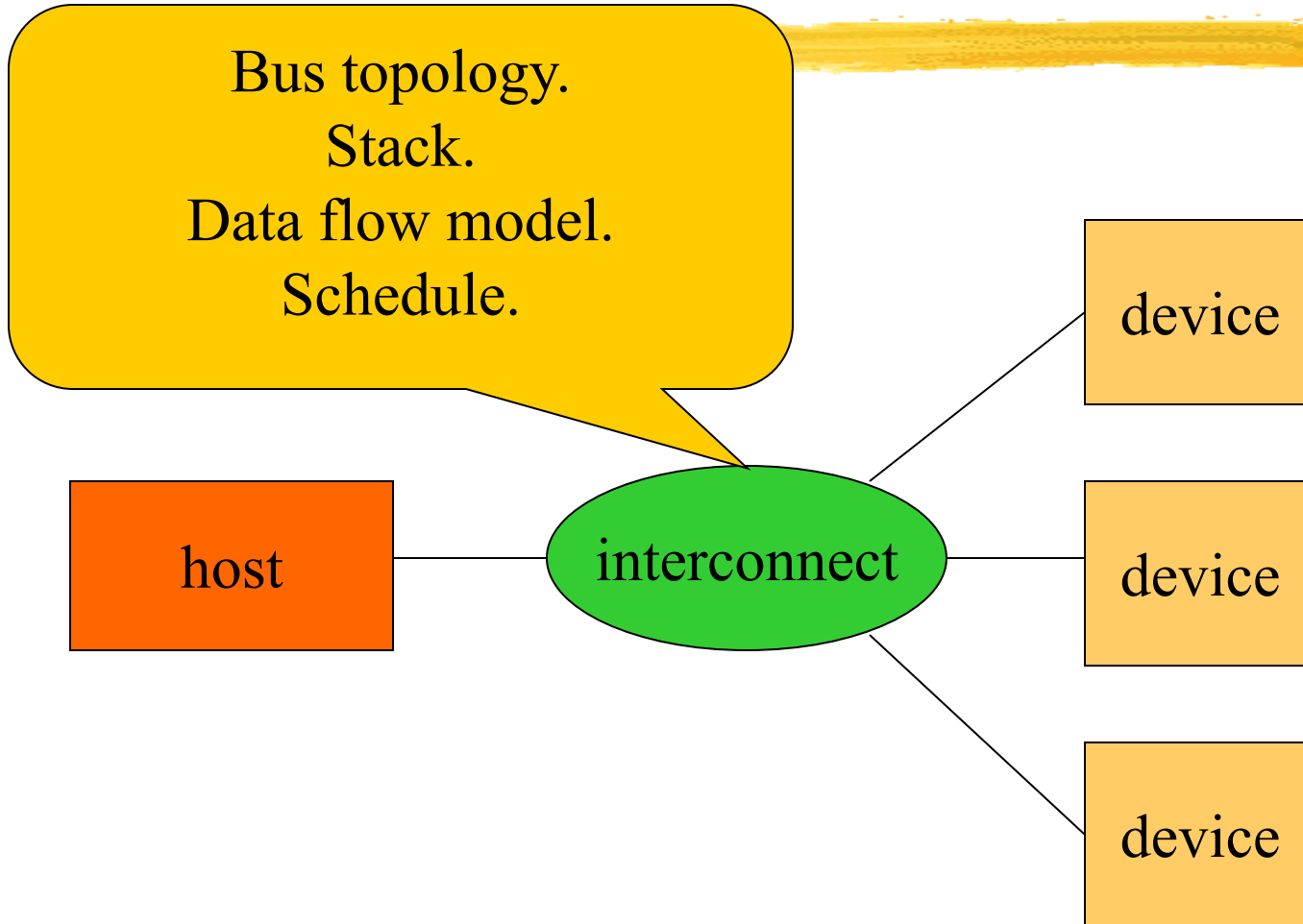
USB 2.0



■ Goals:

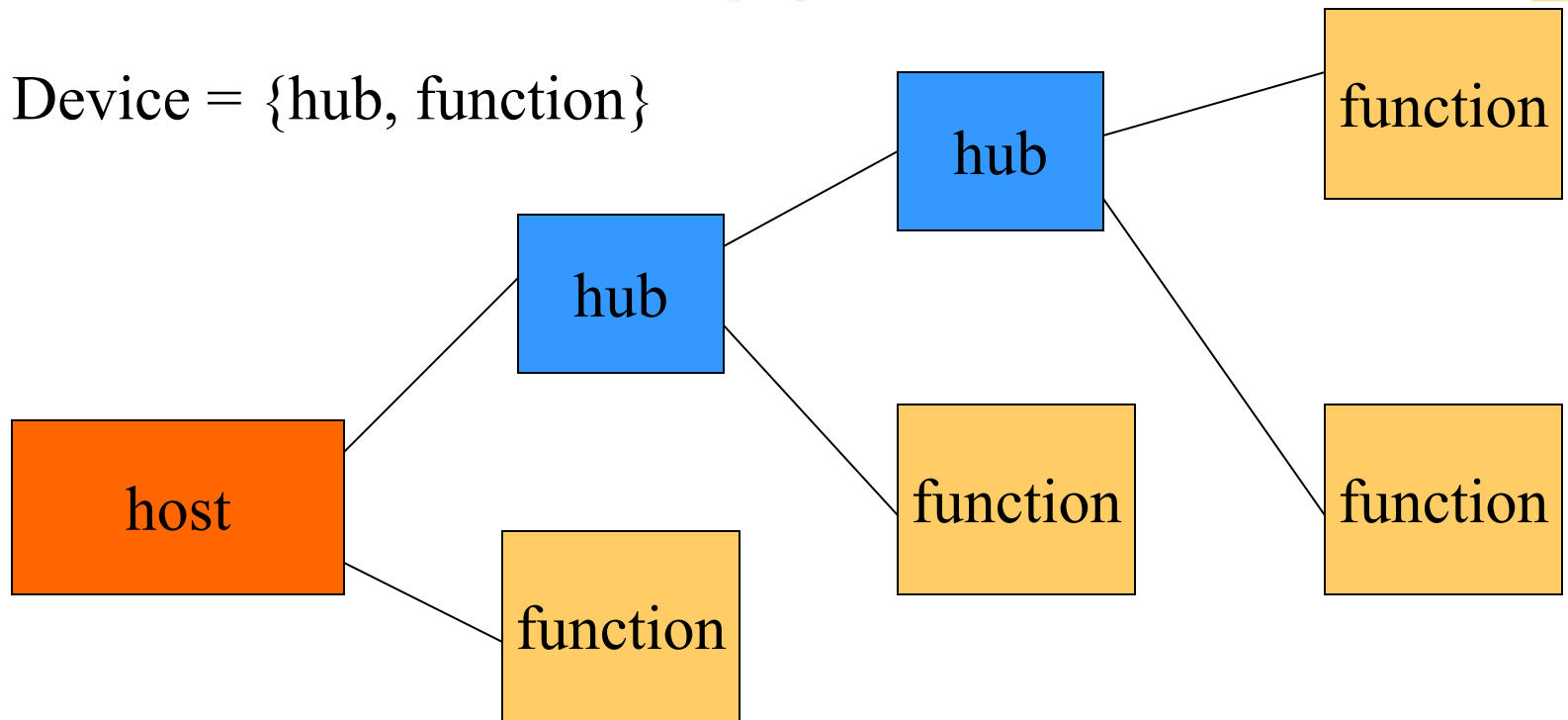
- Easy to use.
- Low cost for consumer devices.
- Up to 480 Mb/s.
- Real-time audio, video.
- Both isochronous and asynchronous communication.

USB architecture



Bus tiers

Device = {hub, function}



Tier 1

tier 2

tier 3

tier 4 tier 7

USB signaling



■ Speeds:

- High-speed is 480 Mb/s.
- Full-speed is 12 Mb/s.
- Low-speed is 1.5 Mb/s.

■ Signals:

- Vbus, Gnd.
- D+, D-.

USB power



- USB devices can pull a limited amount of power from the bus.
 - May also supply their own power.
- System may provide a power-management protocol.
 - Independent of USB.

USB bus protocol



- Polled bus, all transfers initiated by host.
- Basic transaction:
 - Host sends token packet:
 - Type and direction.
 - USB device number.
 - Endpoint number (subdevice).
 - Data transfer packet.
 - Acknowledge packet.

Robustness



- Error detection/correction.
- Automatic handling of device attach/detach.
- Self-recovery in protocol.
- Streaming data management.
- Pipes for data management.

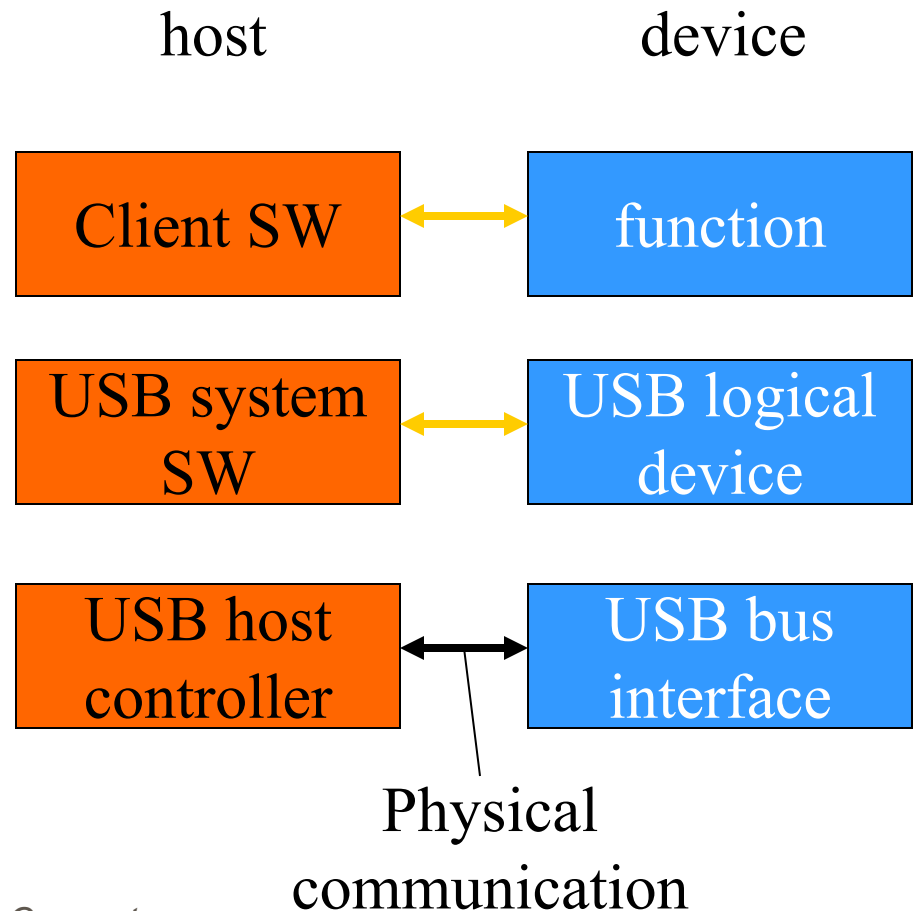
USB pipes



- Functions are allocated to data pipes.
 - Pipes limit interference between functions.
- Bandwidth is allocated among pipes.
- Devices must supply buffer memory.

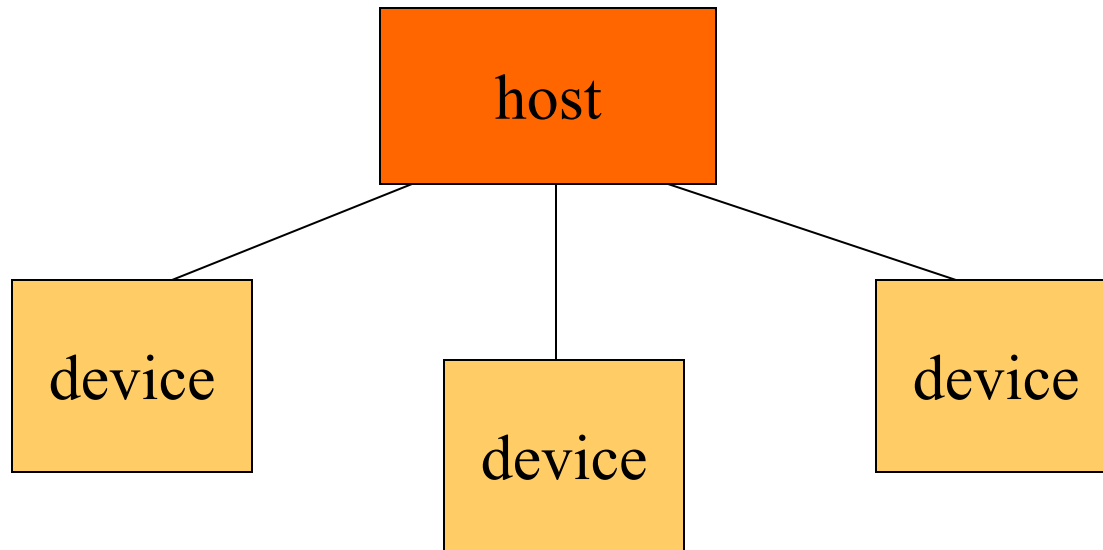
USB data flow model

- Four types of implementation:
 - Device hardware.
 - Client software to connect to application.
 - USB system software.
 - USB host controller (host side system interface).



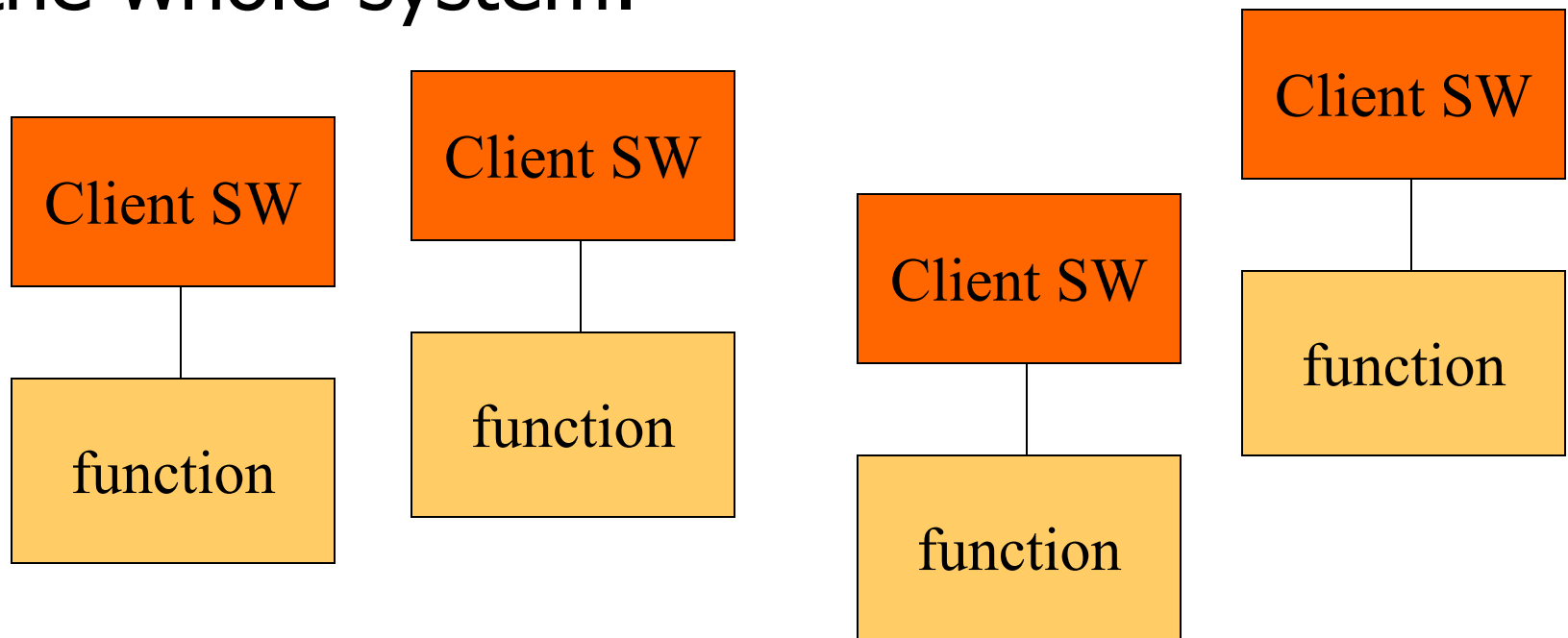
Logical bus topology

- Bus appears to be a simple host/device system:



Client software view

- Each client sees its own function but not the whole system:



Endpoints



- Each logical device is a collection of endpoints.
- Each endpoint is simplex (input or output).
- Endpoint description:
 - Bus frequency/latency.
 - Bandwidth requirement.
 - Endpoint number.
 - Error handling requirements.
 - Maximum packet size.
 - Transfer type.
 - Transfer direction.

Pipes



- Two types of pipes:
 - Stream.
 - Message.
- Pipe description includes:
 - Pipe type.
 - Direction.
 - Bus access and bandwidth.

Bus transfer types



- Data goes through the pipe in FIFO order.
- Four types of transfers:
 - Control.
 - Isochronous—periodic data stream.
 - Interrupt.
 - Bulk—non-periodic, large data transfer.