



Serial Communication

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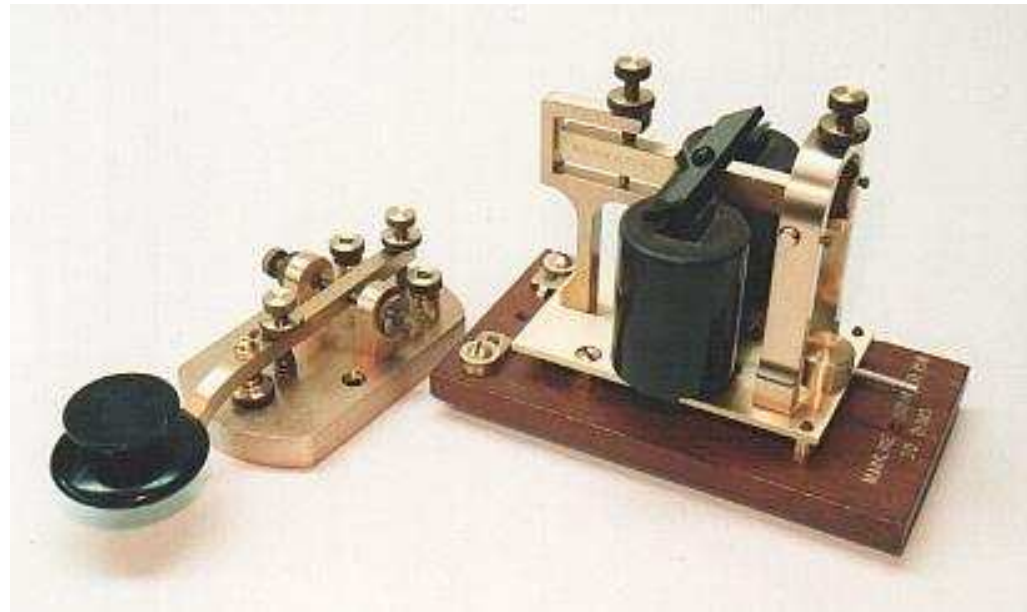
Columbia University

Spring 2011

Early Serial Communication

Morse code key

| Letters | | Numbers | |
|---------|---------|---------|-----------|
| A | •— | 1 | • — — — — |
| B | —••• | 2 | •• — — — |
| C | —•—• | 3 | ••• — — |
| D | —•• | 4 | •••• — |
| E | • | 5 | ••••• |
| F | ••—• | 6 | —•••• |
| G | — —• | 7 | — —••• |
| H | •••• | 8 | — — —•• |
| I | •• | 9 | — — — —• |
| J | • — — — | 0 | — — — — — |
| K | —•— | | |
| L | • —•• | | |
| M | — — | | |
| N | —• | | |
| O | — — — | | |
| P | • — —• | | |
| Q | — —• — | | |
| R | • —• | | |
| S | ••• | | |
| T | — | | |
| U | •• — | | |
| V | ••• — | | |
| W | • — — | | |
| X | —•• — | | |
| Y | —• — — | | |
| Z | — —•• | | |



Later Serial Communication



Data Terminal Equipment



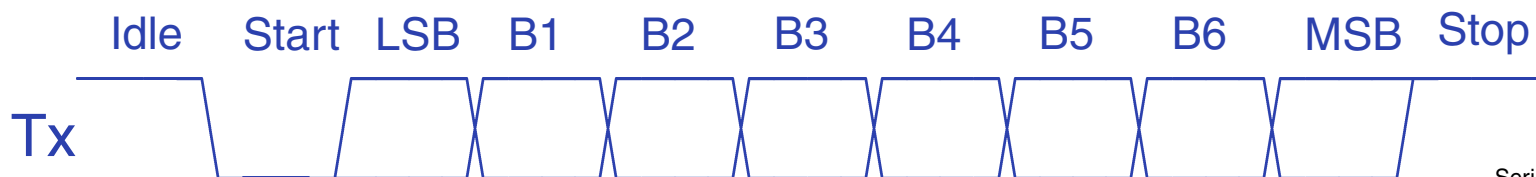
Data
Communications
Equipment

RS-232

Defined in early 1960s
Serial, Asynchronous, Full-duplex,
Voltage-based, point-to-point, 100 ft+ cables

+12V }
+3V } SPACE = 0

-3V }
-12V } MARK = 1



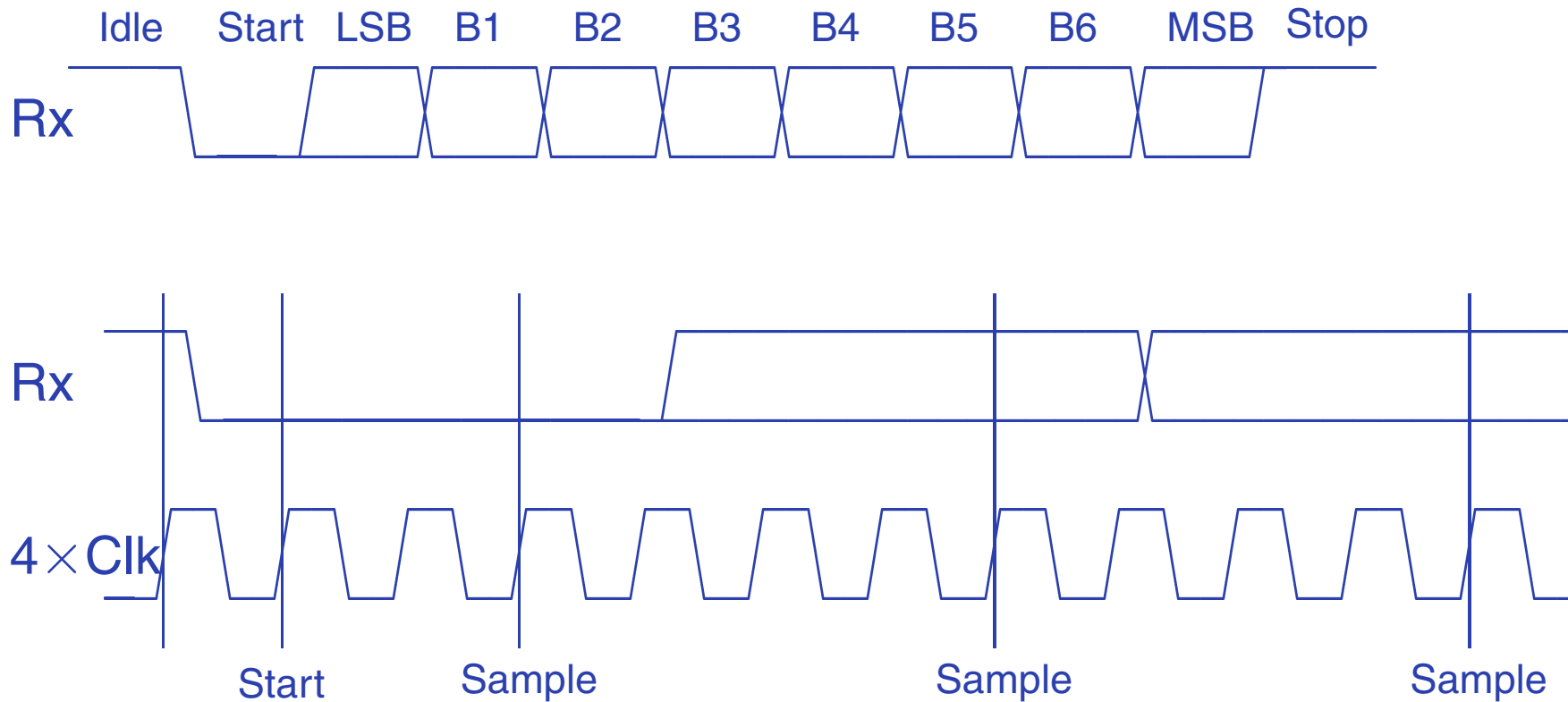
RS-232 Signals



Signal DB-9 DTE ... Meaning

| | pin | DCE | |
|-----|-----|-----|---------------------------------|
| RxD | 2 | ← | Data received by DTE |
| TxD | 3 | → | Data sent by DTE |
| SG | 5 | — | Ground |
| DSR | 6 | ← | Data Set Ready (I'm alive) |
| DTR | 4 | → | Data Terminal Ready (me, too) |
| DCD | 1 | ← | Carrier Detect (hear a carrier) |
| RTS | 7 | → | Request To Send (Yo?) |
| CTS | 8 | ← | Clear To Send (Yo!) |
| RI | 9 | ← | Ring Indicator |

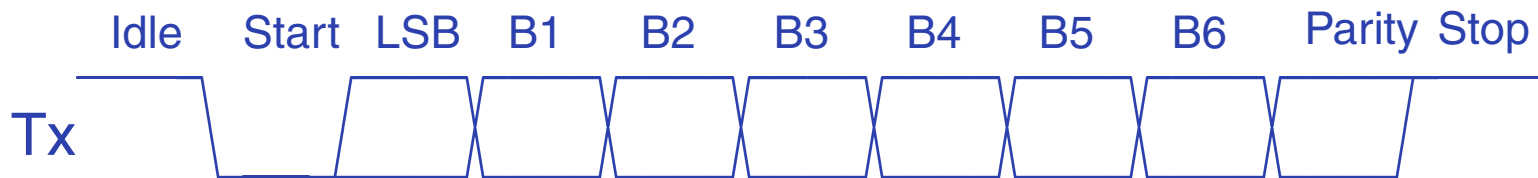
Receiving RS-232



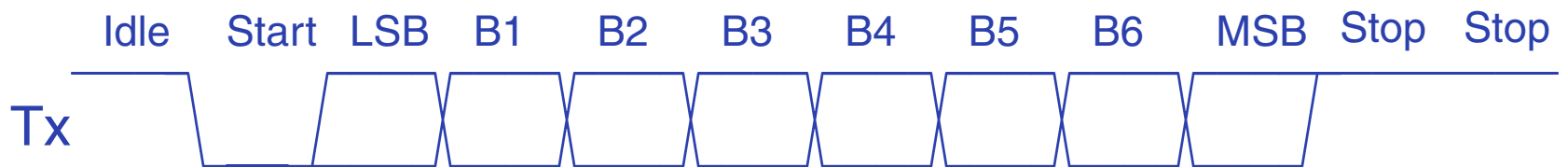
Most UARTs actually use $16\times$ clocks

Variants

Parity bit: (Even = true when even number of 1s)



Two stop bits:



Baud Rate

Baud: bits per second

| Baud | Application |
|-------------|--------------------|
|-------------|--------------------|

| | |
|-----|-----------------|
| 110 | ASR-33 Teletype |
|-----|-----------------|

| | |
|-----|-----------------------|
| 300 | Early acoustic modems |
|-----|-----------------------|

| | |
|------|-------------------------------|
| 1200 | Direct-coupled modems c. 1980 |
|------|-------------------------------|

| | |
|------|----------------|
| 2400 | Modems c. 1990 |
|------|----------------|

| | |
|------|------------------|
| 9600 | Serial terminals |
|------|------------------|

| | |
|-------|--|
| 19200 | |
|-------|--|

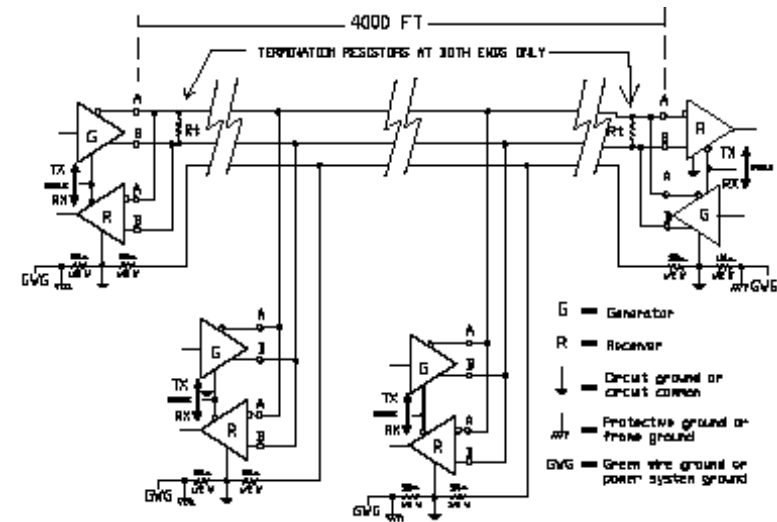
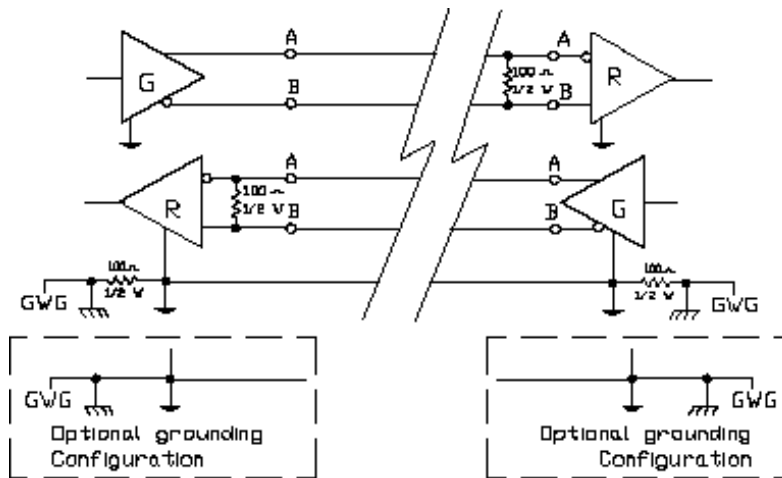
| | |
|-------|-----------------|
| 38400 | Typical maximum |
|-------|-----------------|

Physical Variants

Connectors: DB-25, DB-9, Mini DIN-8

RS-422: Differential signaling

RS-485: Bus-like

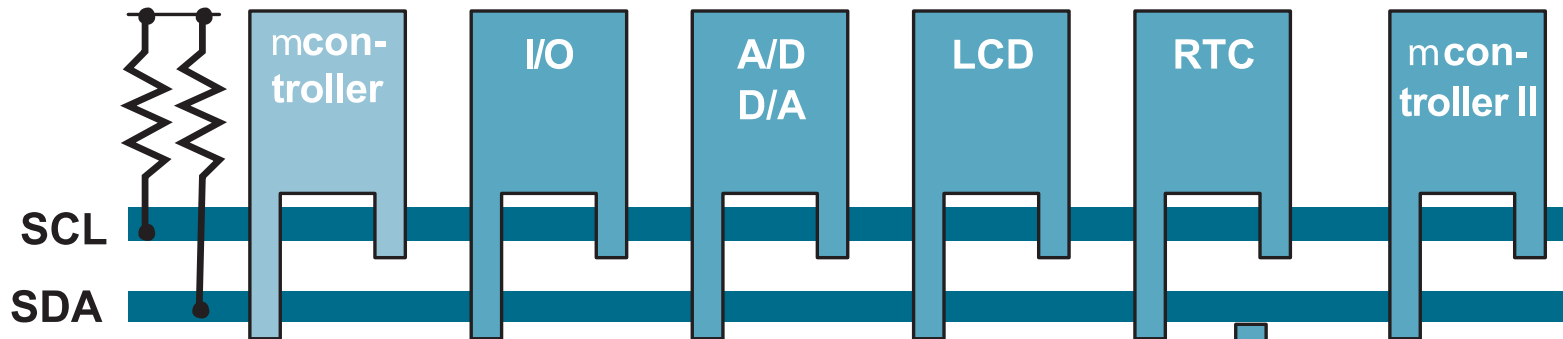


The I²C Bus

Philips invented the Inter-IC bus c. 1980 as a very cheap way to communicate slowly among chips

E.g., good for setting control registers

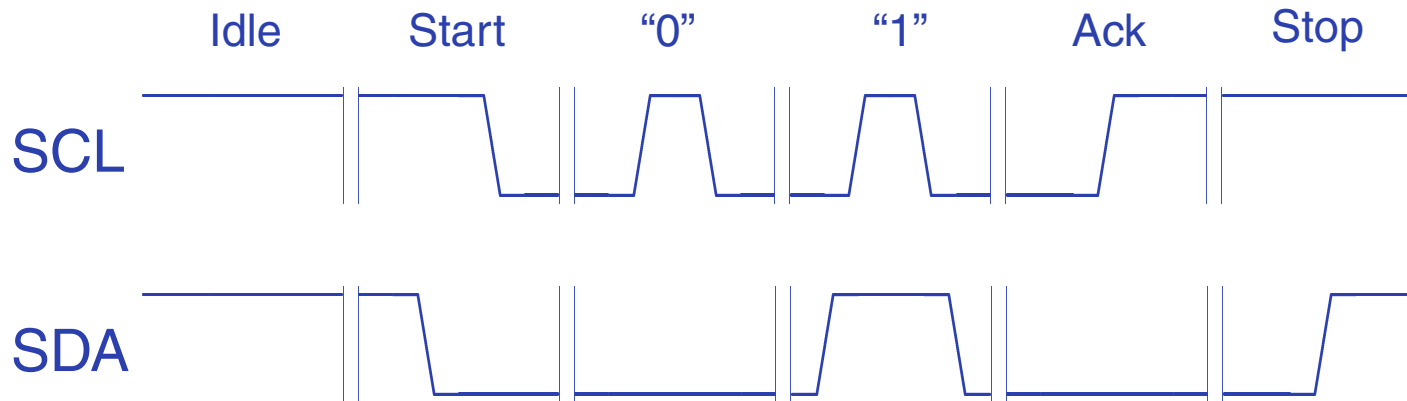
100, 400, and 3400 kHz bitrates



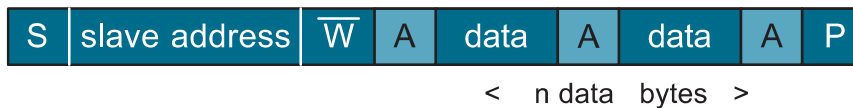
SCL: Clock, generated by a single master

SDA: Data, controlled by either master or slaves

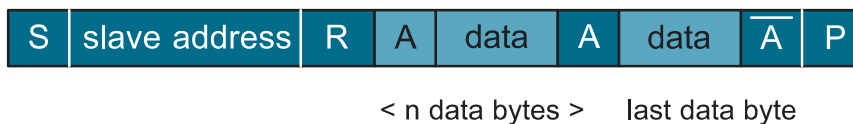
I²C Bus Transaction



Write data



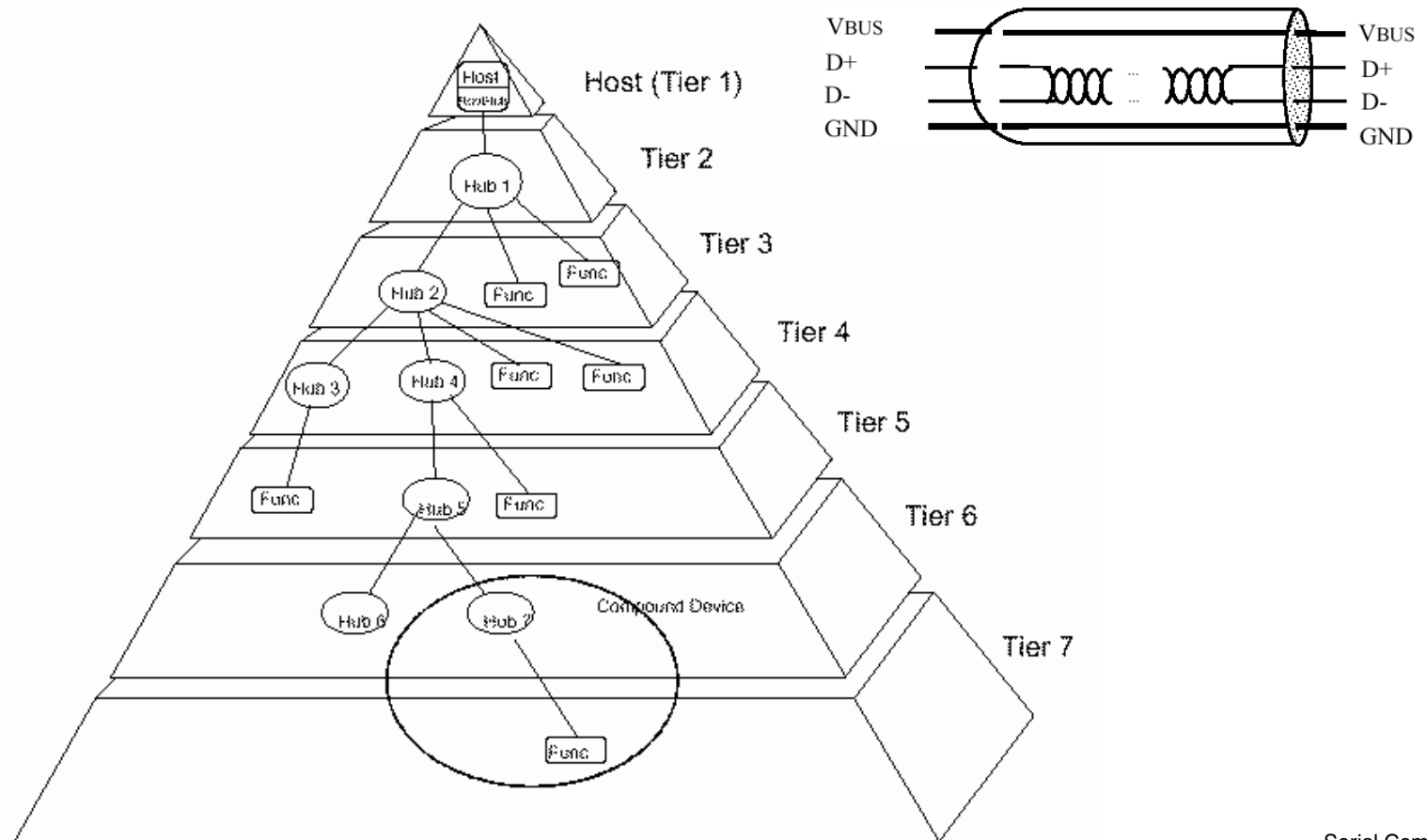
Read data



S = Start condition
 \overline{W} = read / write not
 A = Acknowledge
 \overline{A} = Not Acknowledge
 P = Stop condition

USB: Universal Serial Bus

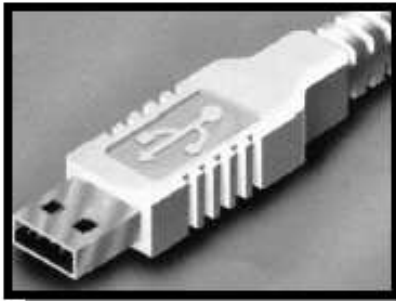
1.5 Mbps, 12 Mbps, and 480 Mbps (USB 2.0)
Point-to-point, differential, twisted pair
3–5m maximum cable length



USB Connectors

Series "A" Connectors

- ◆ Series "A" plugs are always oriented **upstream** towards the *Host System*



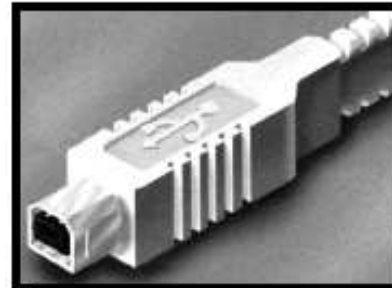
"A" Plugs
(From the
USB Device)

"A" Receptacles
(Downstream Output
from the USB Host or
Hub)



Series "B" Connectors

- ◆ Series "B" plugs are always oriented **downstream** towards the *USB Device*



"B" Plugs
(From the
Host System)

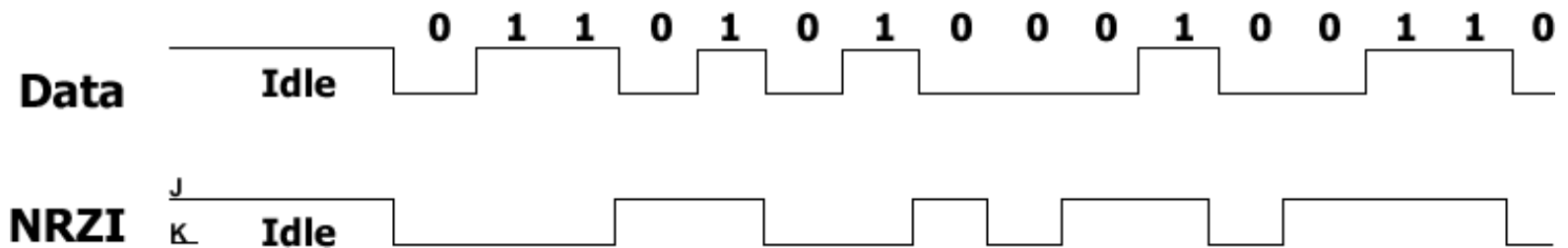
"B" Receptacles
(Upstream Input to the
USB Device or Hub)



USB signaling

NRZI: 0 = toggle, 1 = no change

Bit stuffing: 0 automatically inserted after six consecutive 1s



Each packet prefixed by a SYNC field: 3 0s followed by two 1s

Low- vs. full-speed devices identified by different pull-ups on D+/D- lines

USB Packets

Always start with SYNC

Then 4-bit type, 4-bit type complemented

2 bits distinguish Token, Data, Handshake, and Special, other two bits select sub-types

Then data, depending on packet type

Data checked using a CRC

Addresses (1-128) assigned by bus master, each with 16 possible endpoints

USB Bus Protocol

Polled bus: host initiates all transfers.

Most transactions involve three packets:

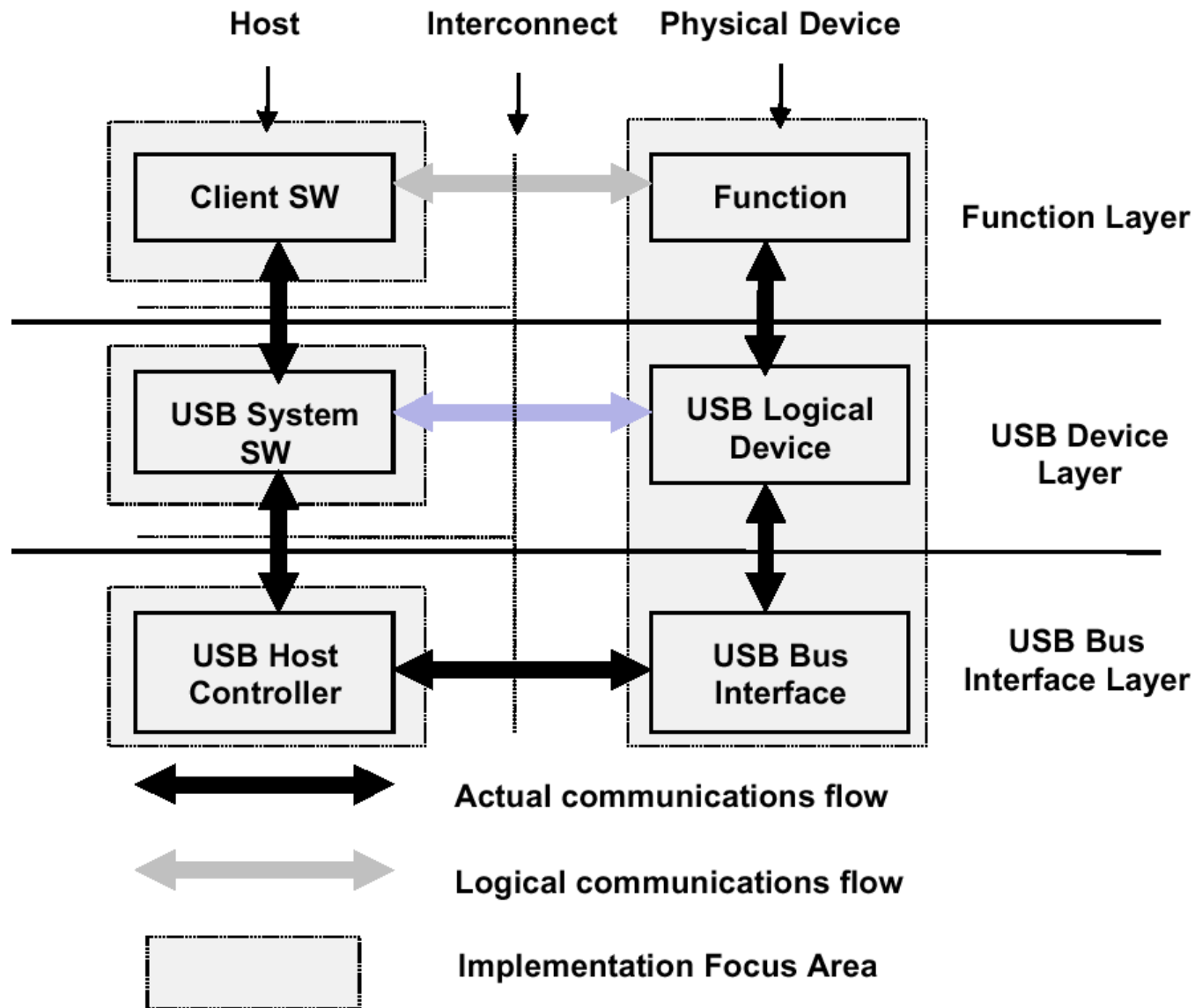
- “Token” packet from host requesting data
- Data packet from target
- Acknowledge from host

Supports both streams of bytes and structured messages (e.g., control changes).

USB Data Flow Types

- Control
For configuration, etc.
- Bulk Data
Arbitrary data stream: bursty
- Interrupt Data
Timely, reliable delivery of data. Usually events.
- Isochronous Data
For streaming real-time transfer:
prenegotiated bandwidth and latency

Layered Architecture



USB: Flash Card Device

```
Bus 001 Device 002: ID 05e3:0760 Genesys Logic, Inc.
bcdUSB                2.00
bMaxPacketSize0      64
idVendor              0x05e3 Genesys Logic, Inc.
idProduct            0x0760
bcdDevice            1.14
iManufacturer        2 Genesys
iProduct             3 Flash Reader
iSerial              4 002364
Configuration Descriptor:
  bNumInterfaces      1
  MaxPower            300mA
  Interface Descriptor:
    bNumEndpoints     2
    bInterfaceClass   8 Mass Storage
    bInterfaceSubClass 6 SCSI
    bInterfaceProtocol 80 Bulk (Zip)
    Endpoint Descriptor:
      bEndpointAddress 0x81 EP 1 IN
      bmAttributes     2
        Transfer Type   Bulk
        Synch Type     none
      wMaxPacketSize   64
    Endpoint Descriptor:
      bLength          7
      bDescriptorType  5
      bEndpointAddress 0x02 EP 2 OUT
      bmAttributes     2
        Transfer Type   Bulk
        Synch Type     none
      wMaxPacketSize   64
  Language IDs: (length=4)
    0409 English(US)
```

USB: Mouse Device

Bus 002 Device 002: ID 04b4:0001 Cypress Semiconductor Mouse

Device Descriptor:

```
bcdUSB          1.00
idVendor        0x04b4 Cypress Semiconductor
idProduct       0x0001 Mouse
bcdDevice       4.90
iManufacturer   1 Adomax Sem.
iProduct        2 USB Mouse
iSerial         0
```

Configuration Descriptor:

```
bNumInterfaces  1
bmAttributes    0xa0
  Remote Wakeup
MaxPower        100mA
```

Interface Descriptor:

```
bNumEndpoints  1
bInterfaceClass 3 Human Interface Devices
bInterfaceSubClass 1 Boot Interface Subclass
bInterfaceProtocol 2 Mouse
iInterface      5 EndPoint1 Interrupt Pipe
```

HID Device Descriptor:

```
bDescriptorType 34 Report
wDescriptorLength 52
```

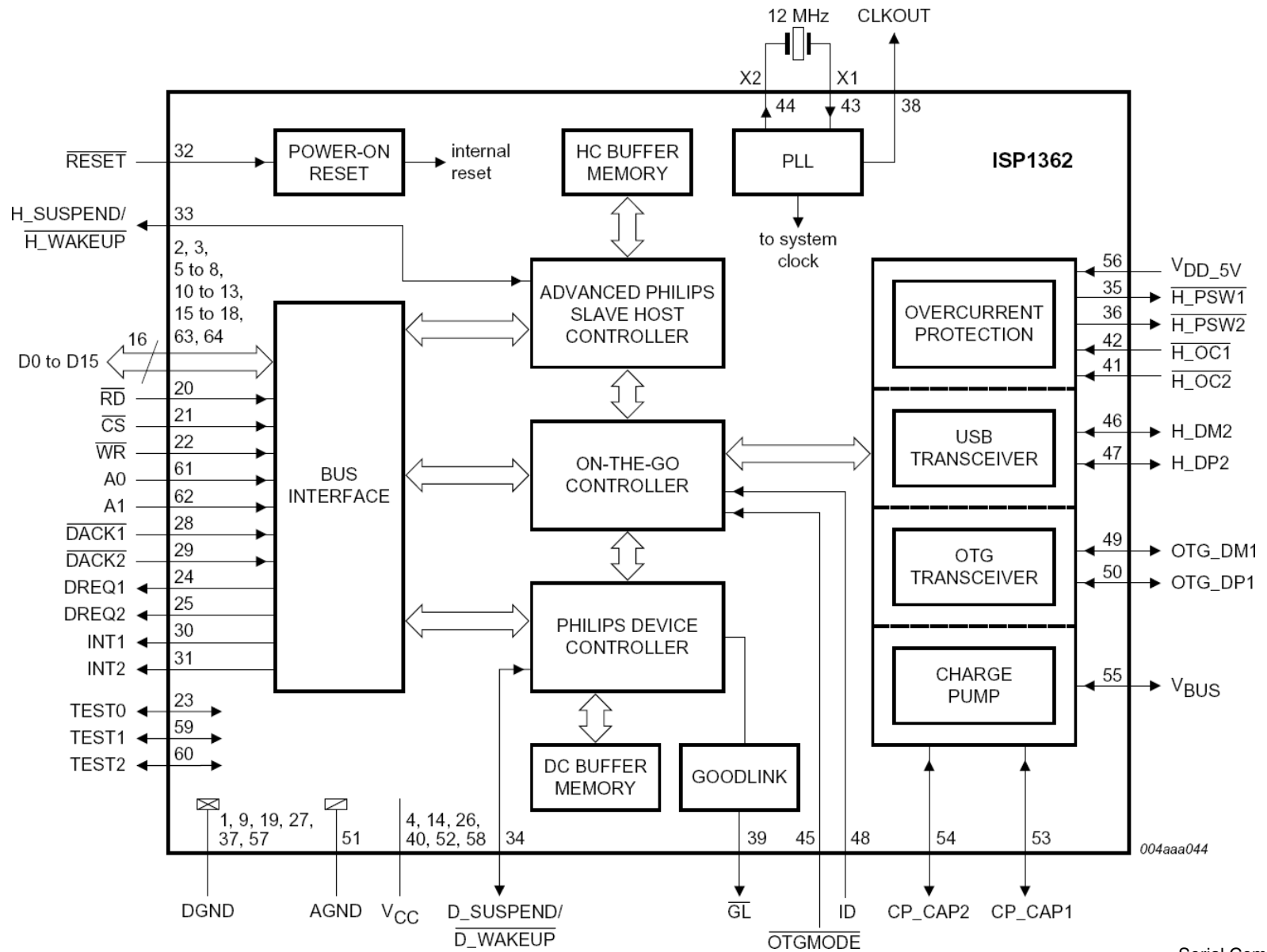
Endpoint Descriptor:

```
bEndpointAddress 0x81 EP 1 IN
bmAttributes      3
  Transfer Type   Interrupt
  Synch Type      none
wMaxPacketSize    4
bInterval         10
```

Language IDs: (length=4)

```
0409 English(US)
```

Philips ISP1362 USB 2.0 Controller



Philips ISP1362 USB 2.0 Controller

On the DE2, one downstream port, one host

Operates at 12 or 480 Mbps speeds

Two control endpoints + 14 user endpoints

4096 (host) + 2462 (device) bytes buffer memory

Supports DMA data transfers

Many configuration and status registers

150-page data “sheet” + 99-page embedded programming guide