Serial Communications

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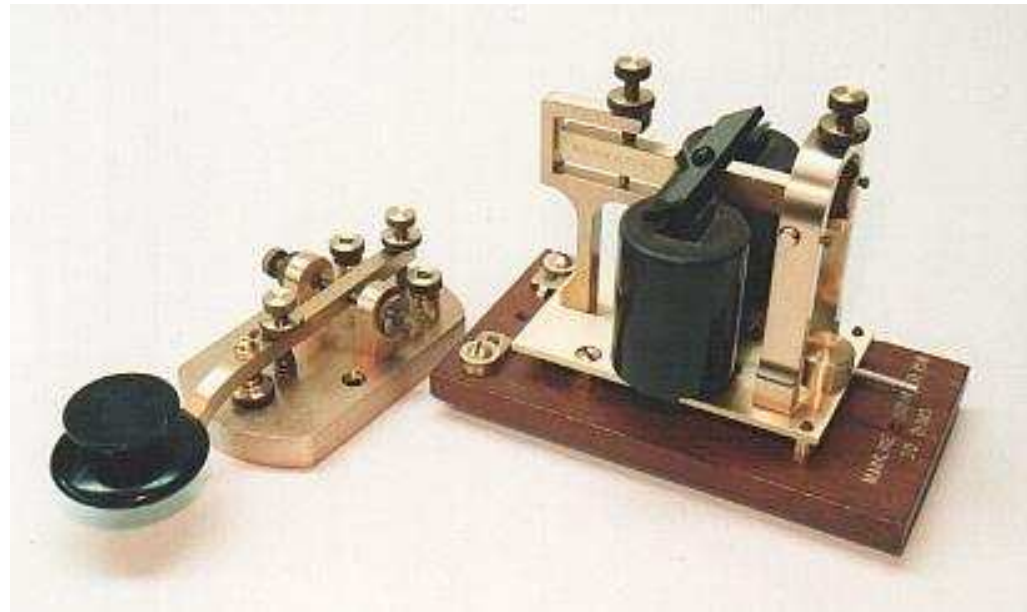
Columbia University

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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	— — • •		

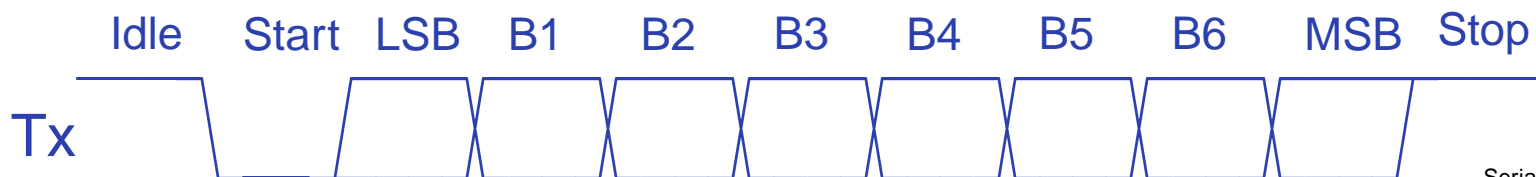# Later Serial Communication

Data Terminal Equipment

Data Communications Equipment

RS-232

Defined in early 1960s
Serial, Asynchronous, Full-duplex,
Voltage-based, point-to-point, 100 ft+ cables
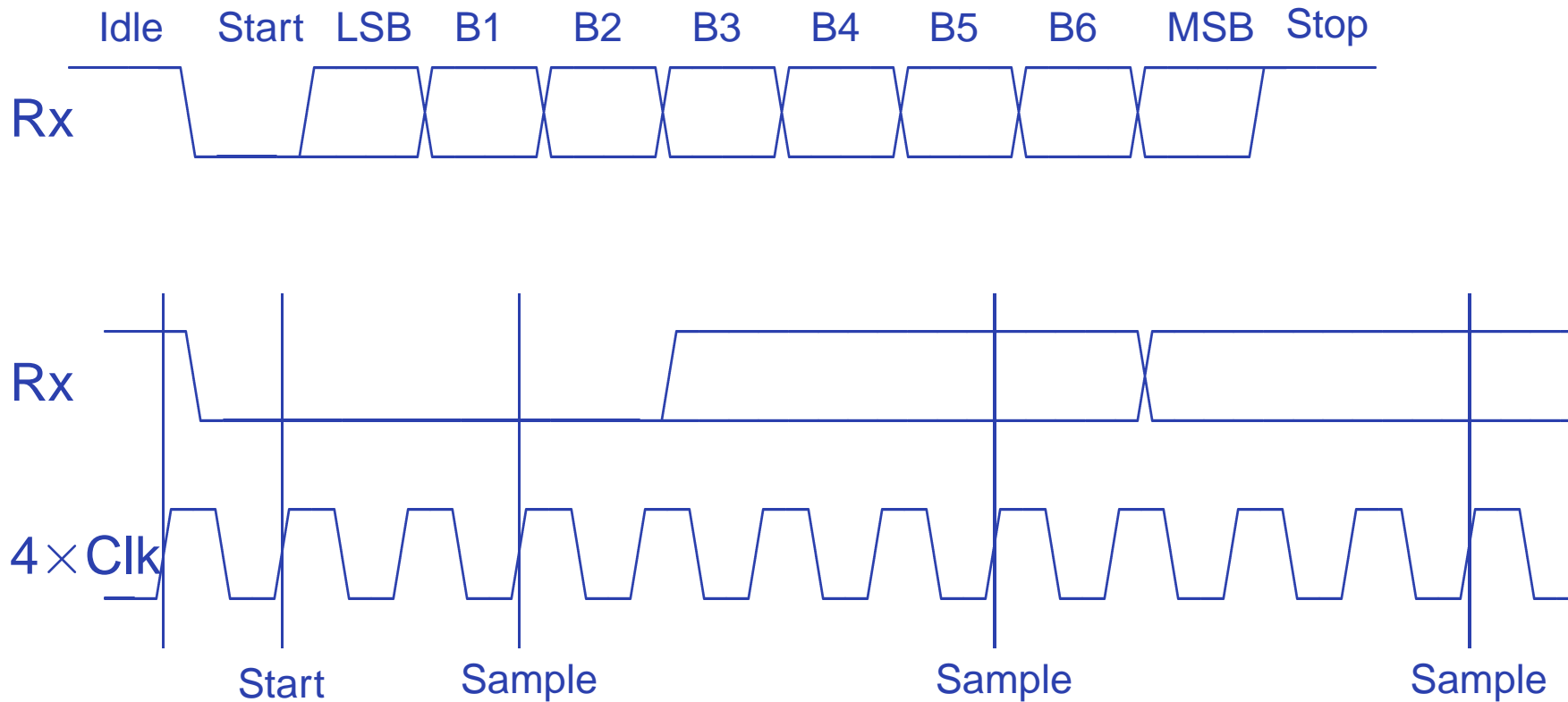
+12V
+3V
} SPACE = 0

−3V
−12V
} MARK = 1

| Idle | Start | LSB | B1 | B2 | B3 | B4 | B5 | B6 | MSB | Stop |

Tx

RS-232 Signals

Signal DB-9 DTE ... Meaning
pin   DCE

Signal	pin	DTE...DCE	Meaning
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

Idle Start LSB B1 B2 B3 B4 B5 B6 MSB Stop

Rx

Rx

$4\times$Clk

Start   Sample   Sample   Sample

Most UARTs actually use $16\times$ clocks

Variants

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

| Idle | Start | LSB | B1 | B2 | B3 | B4 | B5 | B6 | Parity | Stop |

Tx

Two stop bits:

| Idle | Start | LSB | B1 | B2 | B3 | B4 | B5 | B6 | MSB | Stop | Stop |

Tx
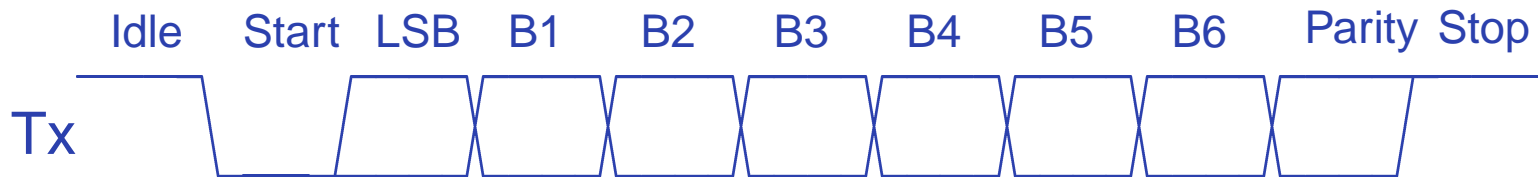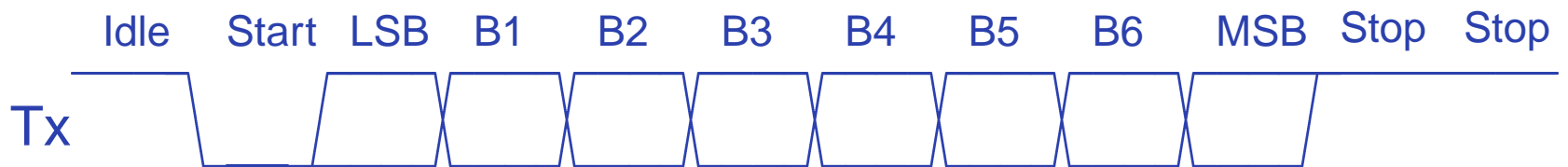
Baud Rate

Baud: bits per second

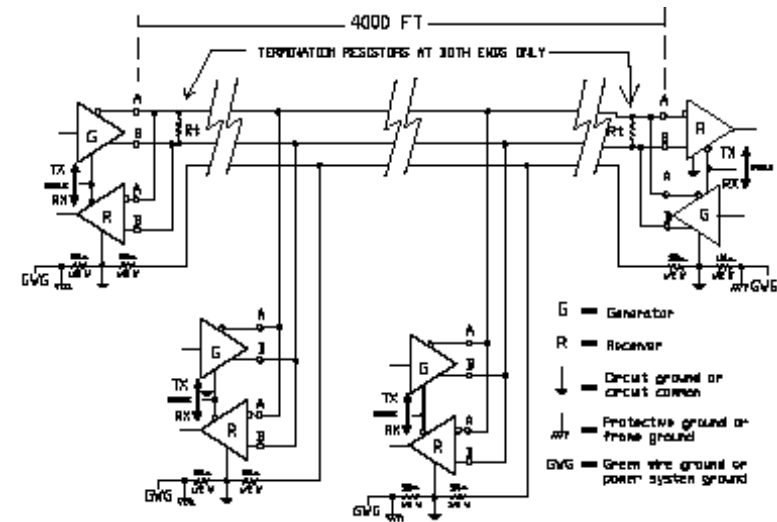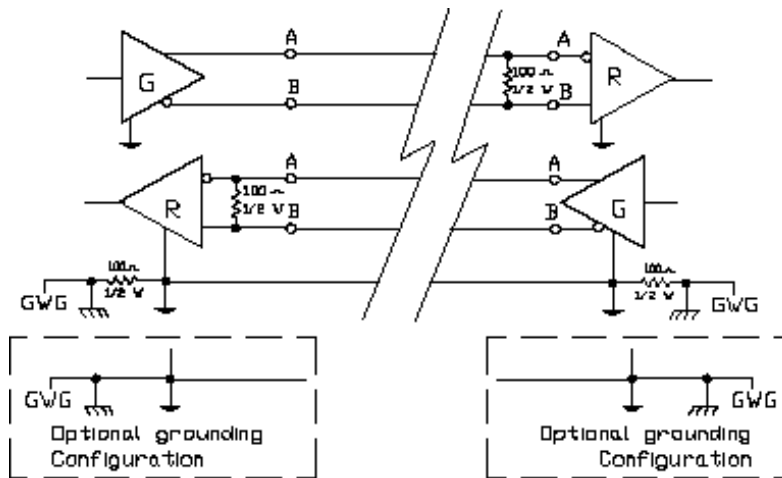| Baud	Application
110	ASR-33 Teletype
300	Early acoustic modems
1200	Direct-coupled modems c. 1980
2400	Modems c. 1990
9600	Serial terminals
19200	
38400	Typical maximum

Physical Variants

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

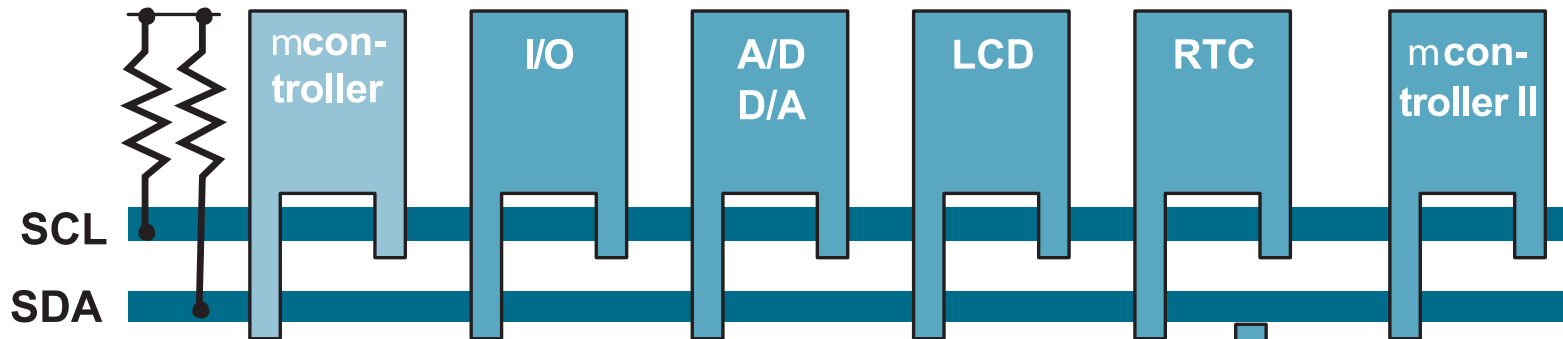RS-422: Differential signaling   RS-485: Bus-like

The I^{2}C Bus

Philips invented the Inter-IC bus c. 1980 as a very cheap way to communicate slowly among chips
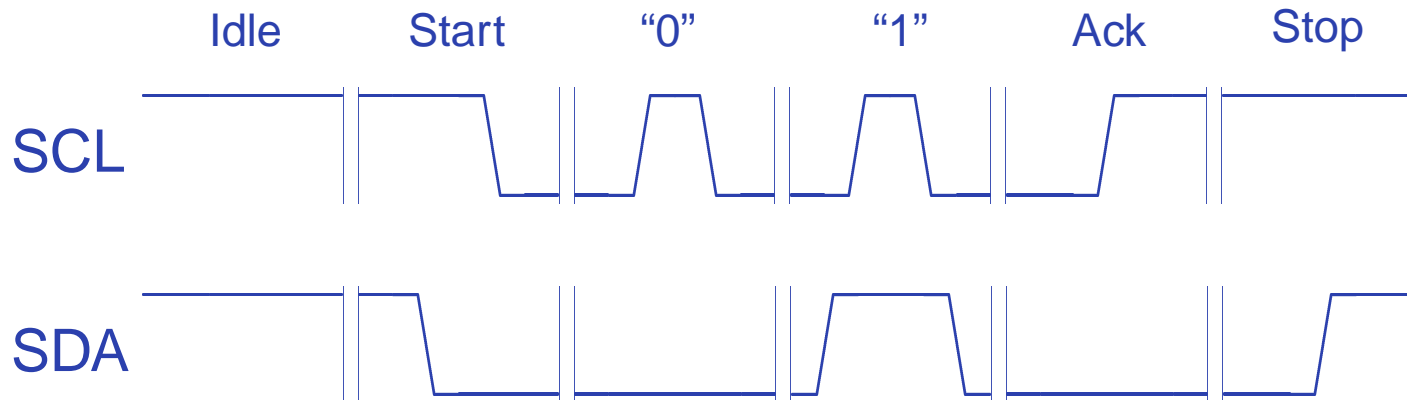
E.g., good for setting control registers
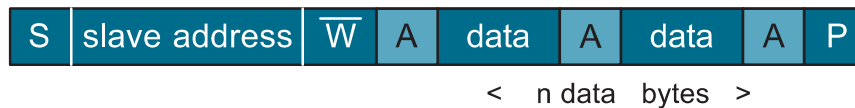
100, 400, and 3400 kHz bitrates

SCL: Clock, generated by a single master

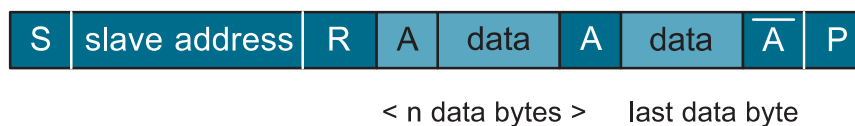SDA: Data, controlled by either master or slaves

I²C Bus Transaction

	Idle	Start	"0"	"1"	Ack	Stop

SCL

SDA

Write data

S	slave address	$\overline{W}$	A	data	A	data	A	P

< n data bytes >

Read data

S	slave address	R	A	data	A	data	$\overline{A}$	P

< n data bytes >   last data byte

Master   Slave

transmitter		receiver

receiver		transmitter

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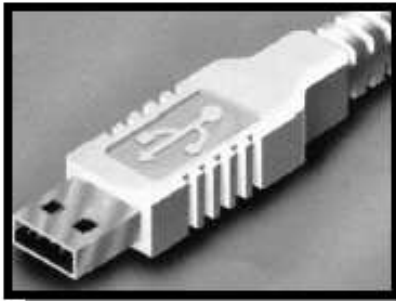P = Stop condition

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
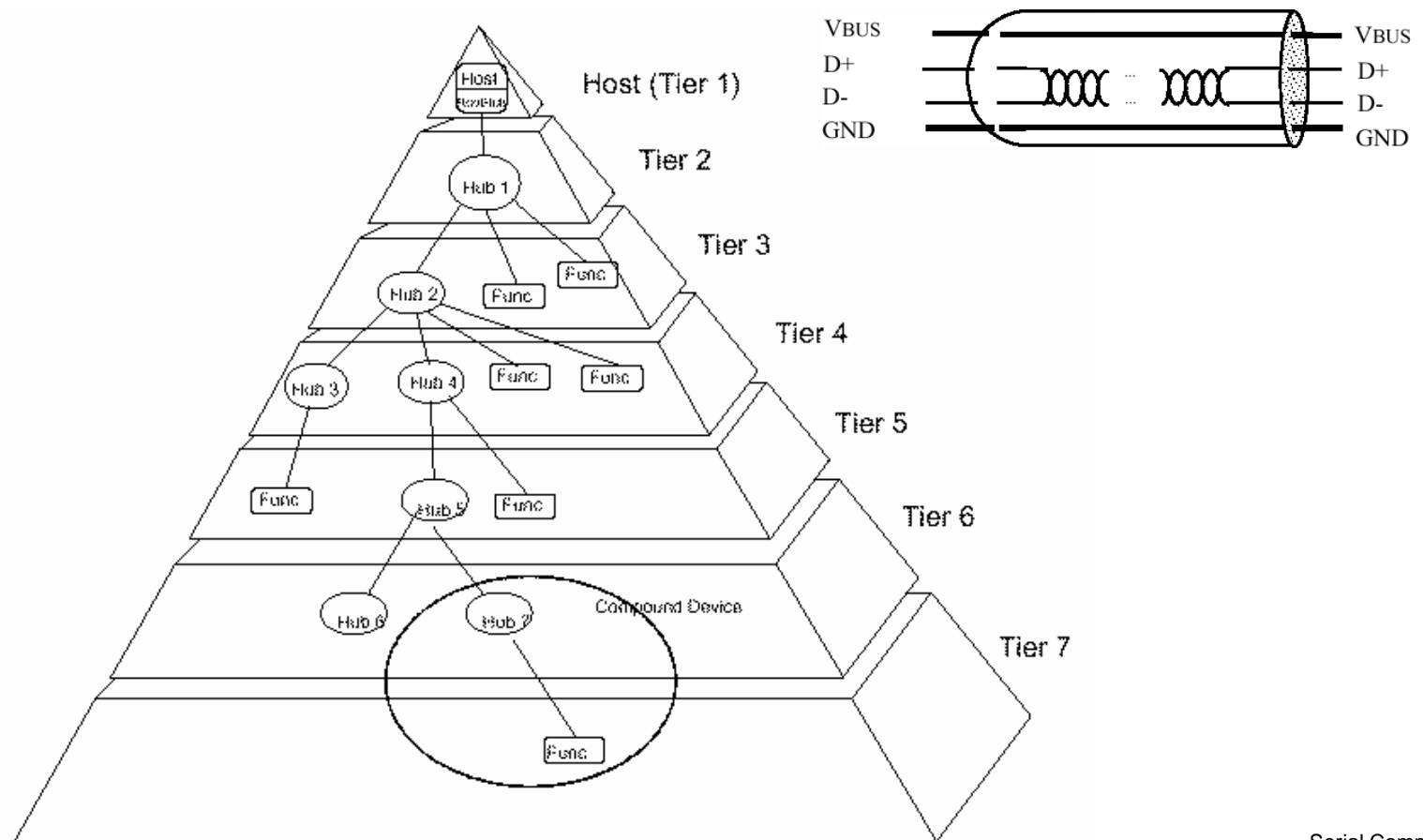
USB Connectors

Series "A" Connectors	Series "B" Connectors
♦ Series "A" plugs are always oriented **upstream** towards the *Host System*	♦ Series "B" plugs are always oriented **downstream** towards the *USB Device*

"A" Plugs
(*From the USB Device*)
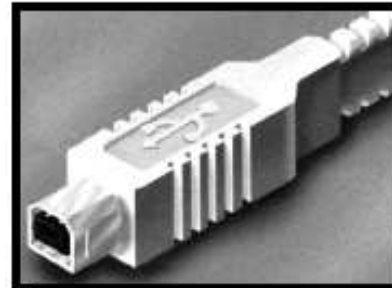
"B" Plugs
(*From the Host System*)

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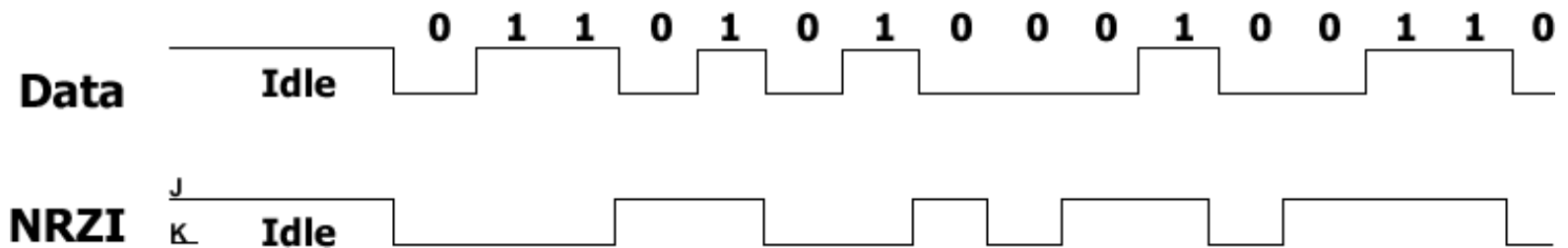(*Downstream Output from the USB Host or Hub*)

"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
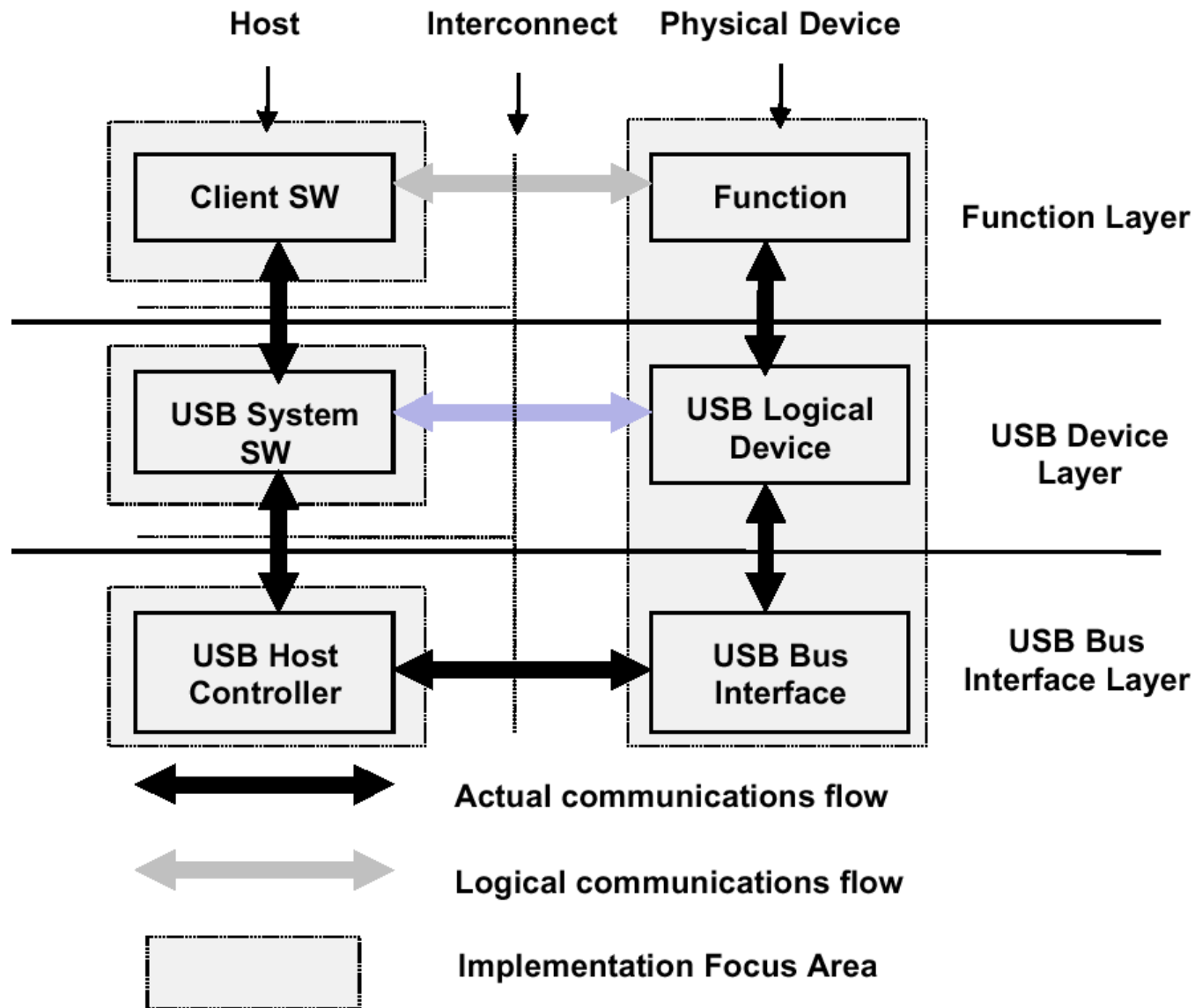
USB: Flash Card Device

```
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)
```
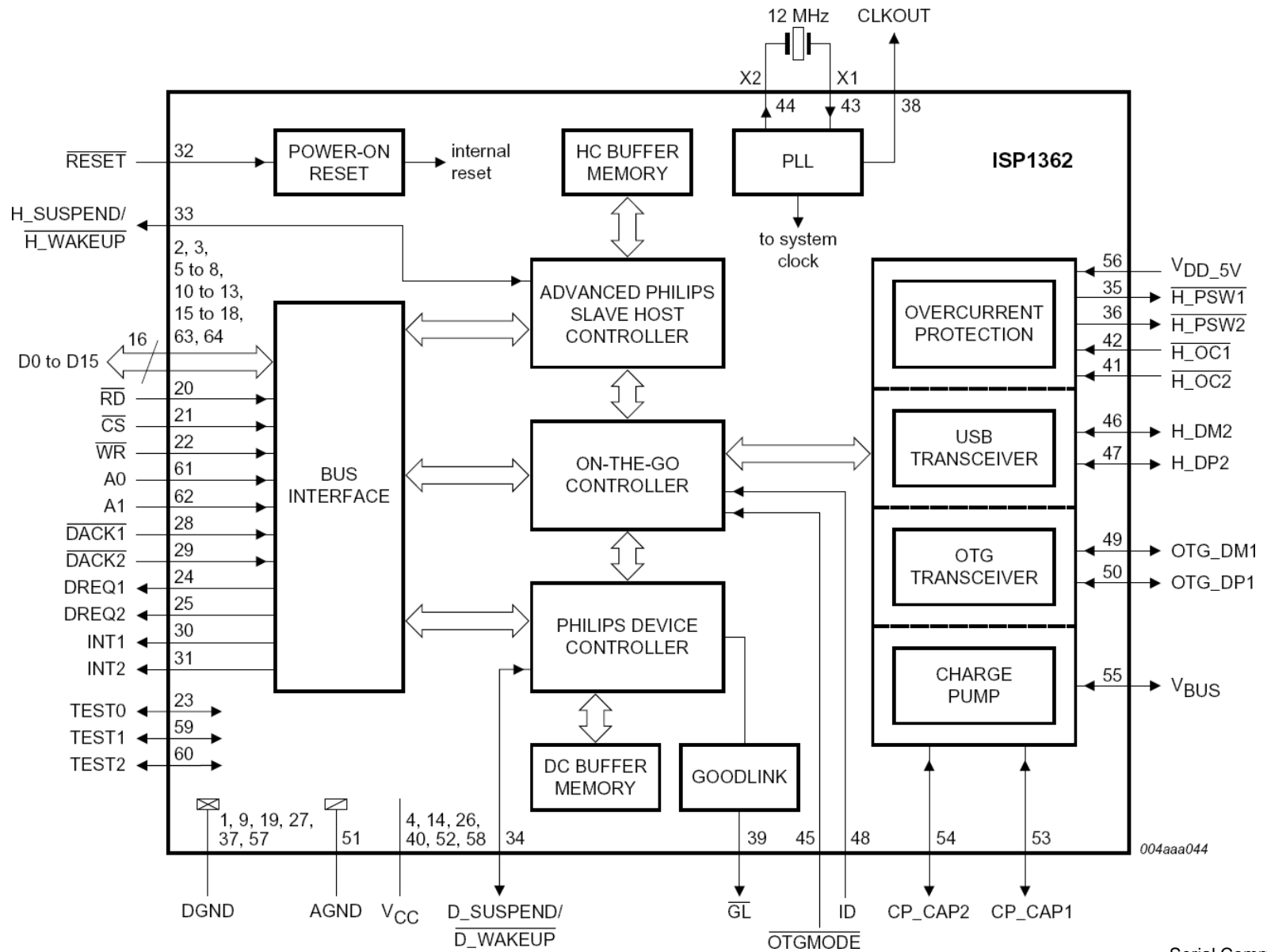
004aaa044

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