Serial Communications

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Early Serial Communication

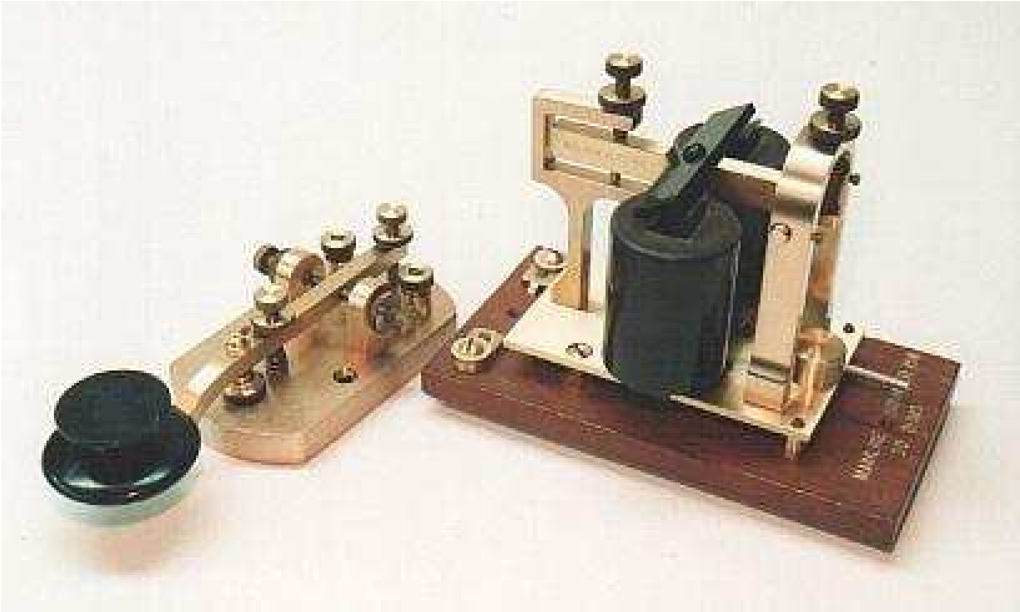
Morse code key

Letters

A	• —
B	— • • •
C	— • — •
D	— • •
E	•
F	• • — •
G	— — •
H	• • • •
I	• •
J	• — — —
K	— • —
L	• — • •
M	— —
N	— •
O	— — —
P	• — — •
Q	— — • —
R	• — •
S	• • •
T	—
U	• • —
V	• • • —
W	• — —
X	— • • —
Y	— • — —
Z	— — • •

Numbers

1	• — — — —
2	• • — — —
3	• • • — —
4	• • • • —
5	• • • • •
6	— • • • •
7	— — • • •
8	— — — • •
9	— — — — •
0	— — — — —



Later Serial Communication

Data Terminal Equipment

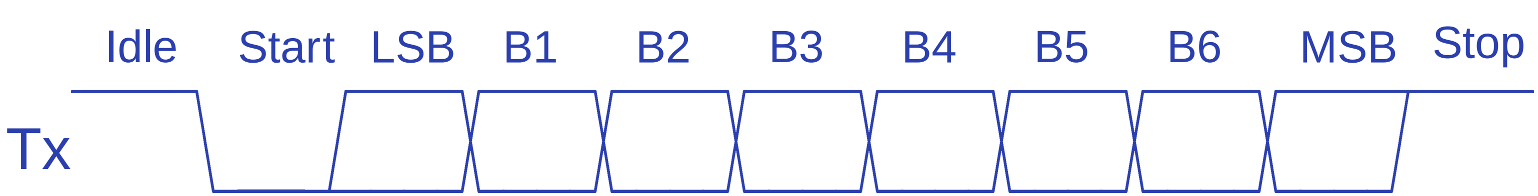
Data Communications Equipment

RS-232

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

$$\left.\begin{array}{r} +12\text{V} \\ \\ +3\text{V} \end{array}\right\} \text{SPACE} = 0$$

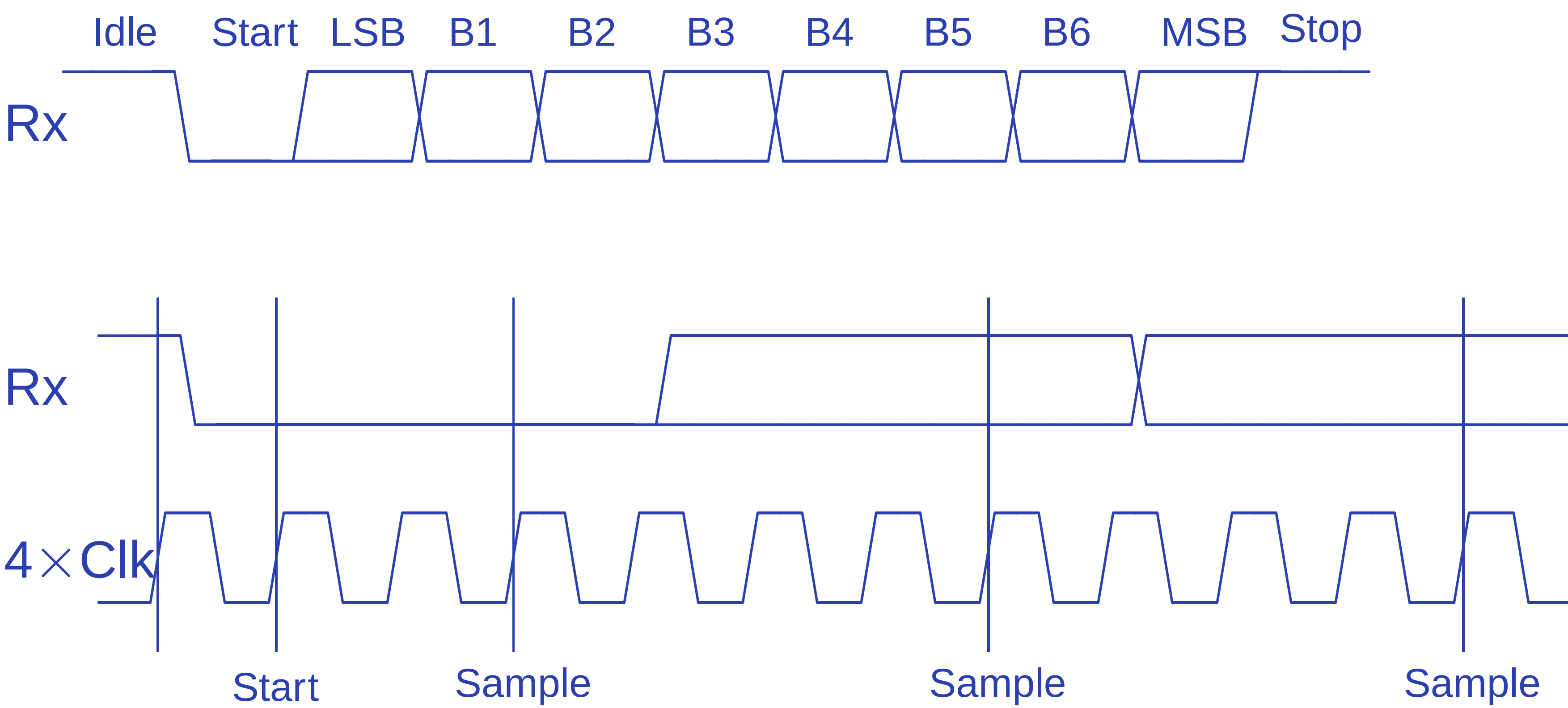
$$\left.\begin{array}{r} -3\text{V} \\ \\ -12\text{V} \end{array}\right\} \text{MARK} = 1$$



RS-232 Signals

Signal	DB-9 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

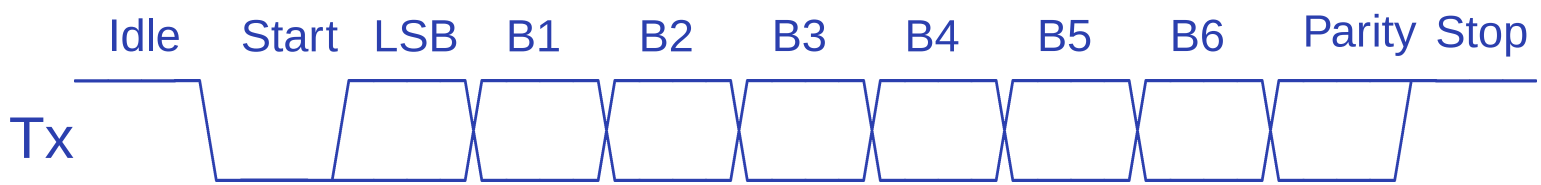
Receiving RS-232



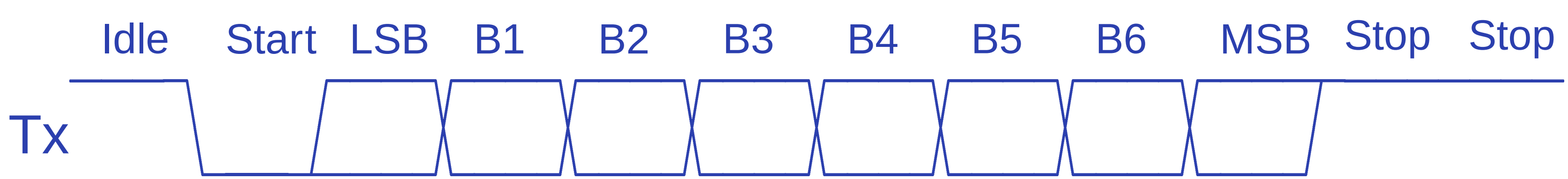
Most UARTs actually use 16× clocks

Variants

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



Two stop bits:



Baud Rate

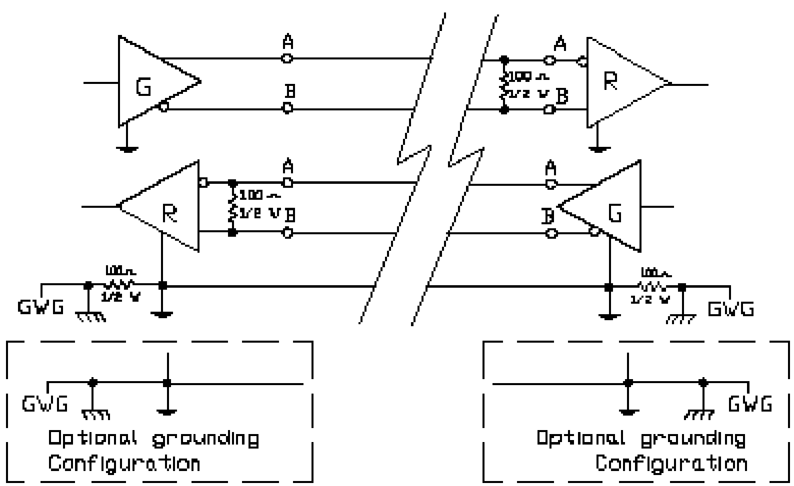
Baud: bits per second

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

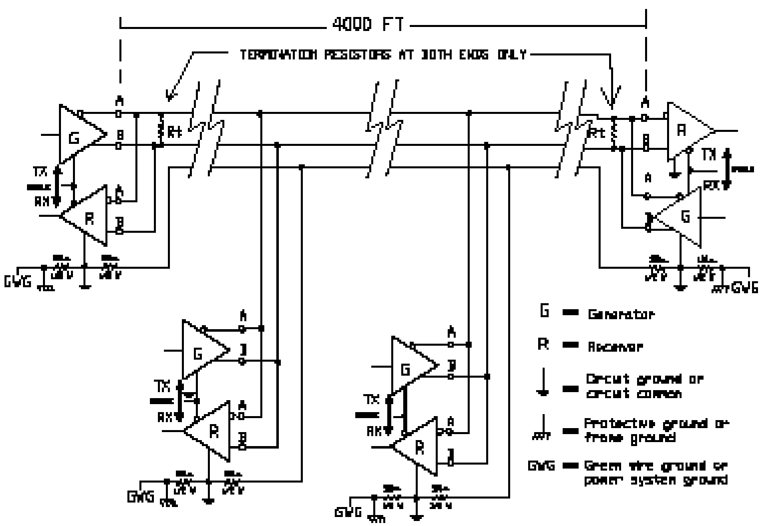
Physical Variants

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

RS-422: Differential signaling



RS-485: Bus-like



OPB UART Lite

Serial port peripheral for the Microblaze

Full duplex operation

16-character transmit and receive FIFOs

Parameters that can be set at build time:

Parameter	**Value**
Base Address	0xFEFF0100
High Address	0xFEFF01FF
Baud Rate	9600
Bits per frame	8
Parity	None

OPB UART Lite Registers

Address	**Role**
`0xFEFF0100`	Read characters from Receive FIFO
`0xFEFF0104`	Write characters to Receive FIFO
`0xFEFF0108`	Status register (read only)
`0xFEFF010C`	Control register (write only)

Status and Control Registers

Bit	Status	Control
24	Parity Error	-
25	Framing Error	-
26	Overrun Error	-
27	Interrupts Enabled	Enable Interrupts
28	Tx buffer full	-
29	Tx buffer empty	-
30	Rx buffer full	Clear Rx buffer
31	Rx buffer non-empty	Clear Tx buffer

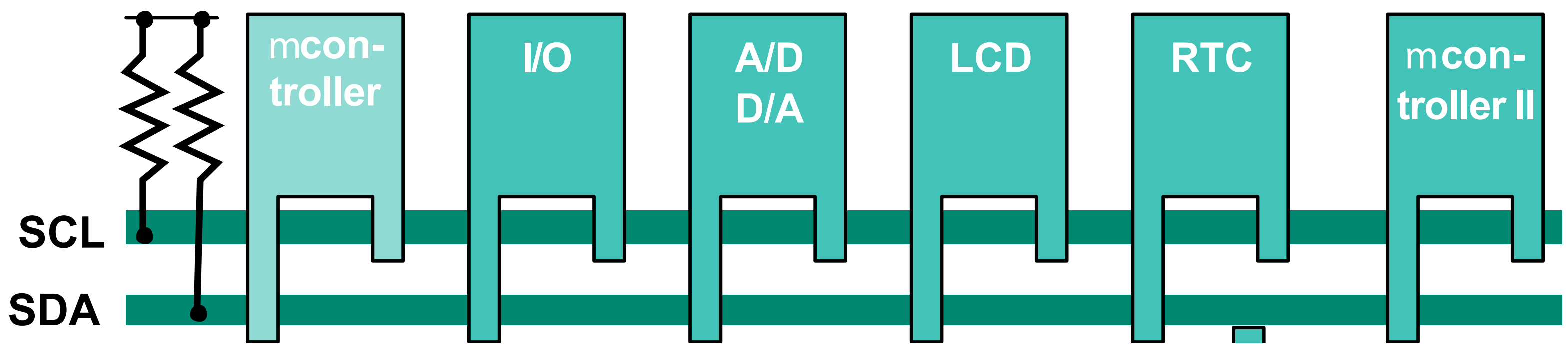
Non-empty Rx buffer or emptying of Tx buffer generates an interrupt.

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

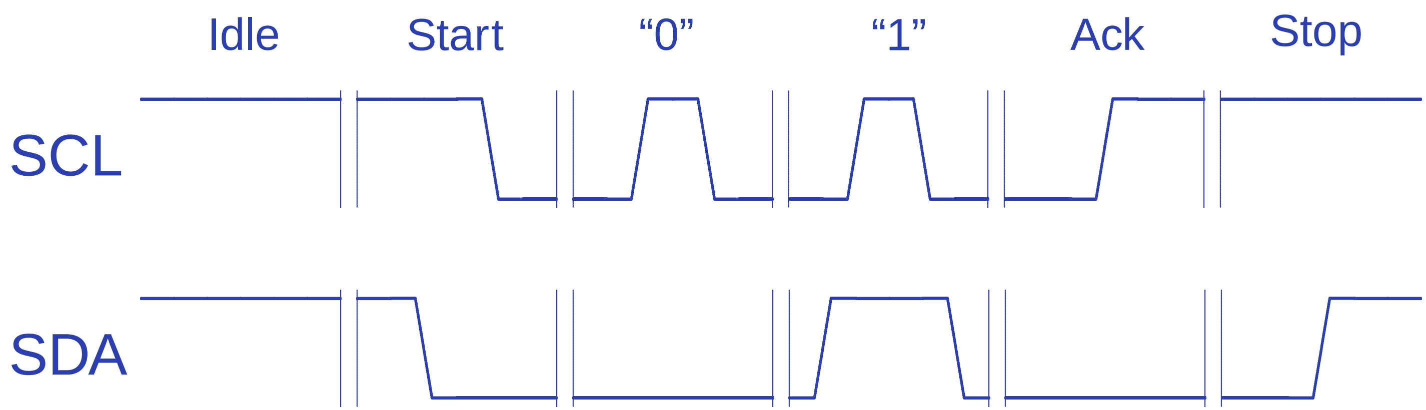
100, 400, and 3400 kHz bitrates

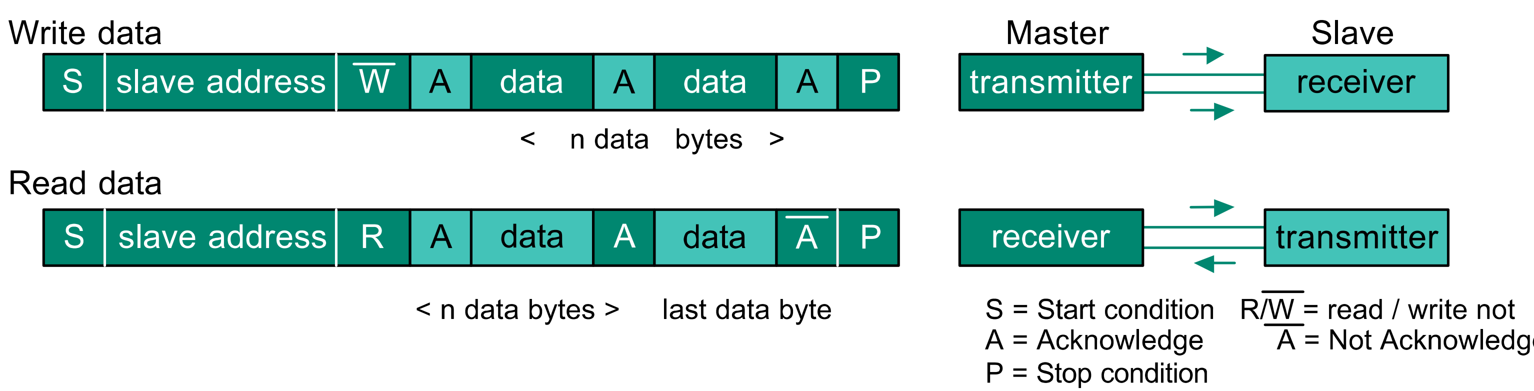


SCL: Clock, generated by a single master

SDA: Data, controlled by either master or slaves

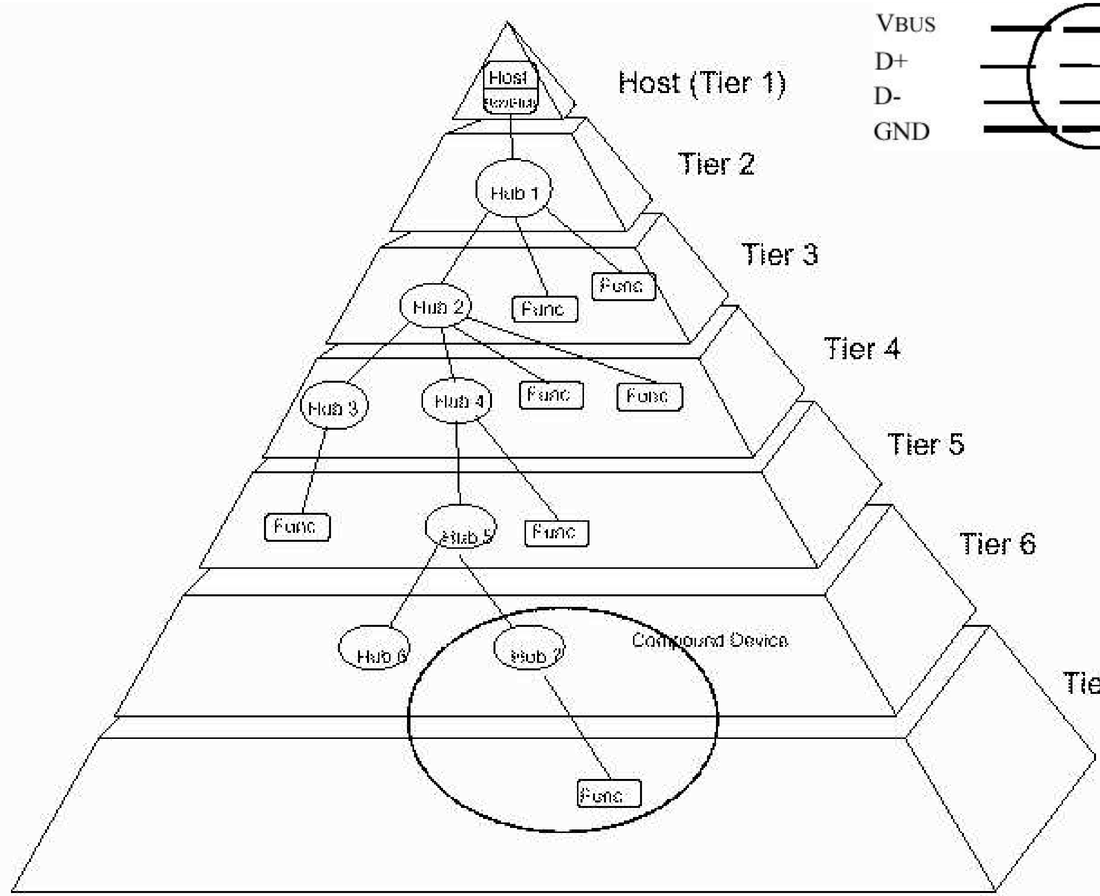
I^2C Bus Transaction

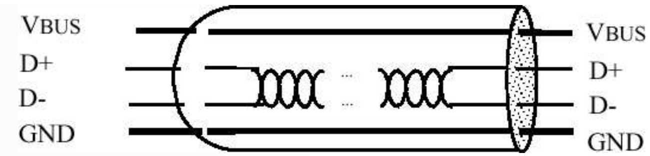




USB: Universal Serial Bus

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

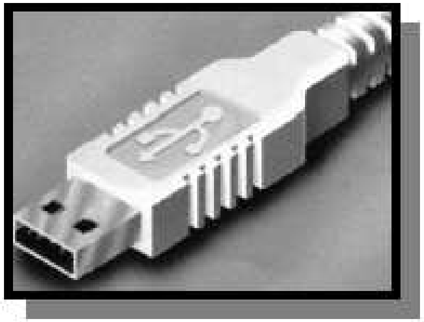




USB Connectors

Series "A" Connectors

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

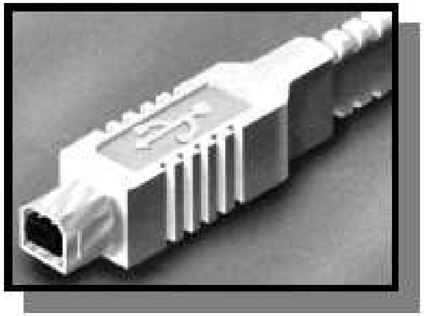


"A" Plugs
(*From the USB Device*)

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

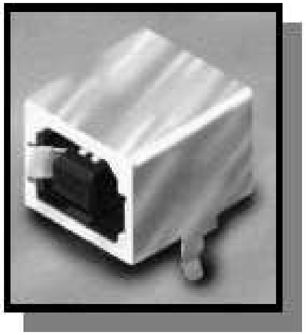
Series "B" Connectors

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



"B" Plugs
(*From the Host System*)

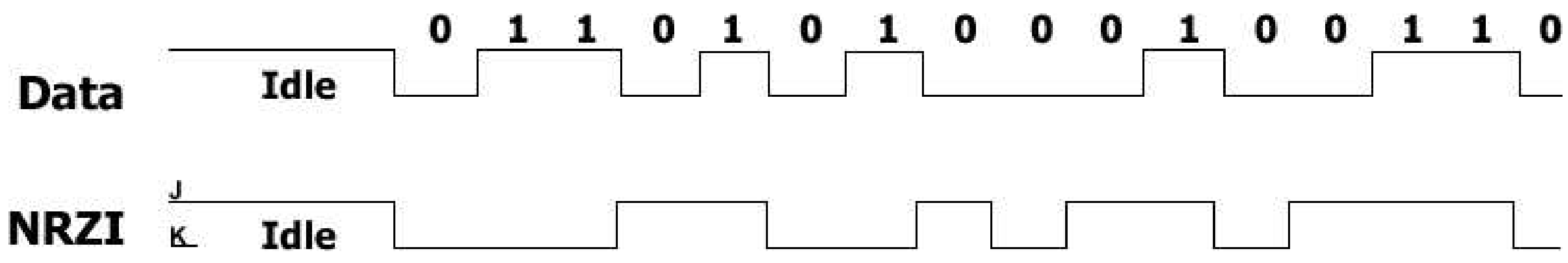
"B" Receptacles
(*Upstream Input to the USB Device or Hub*)



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

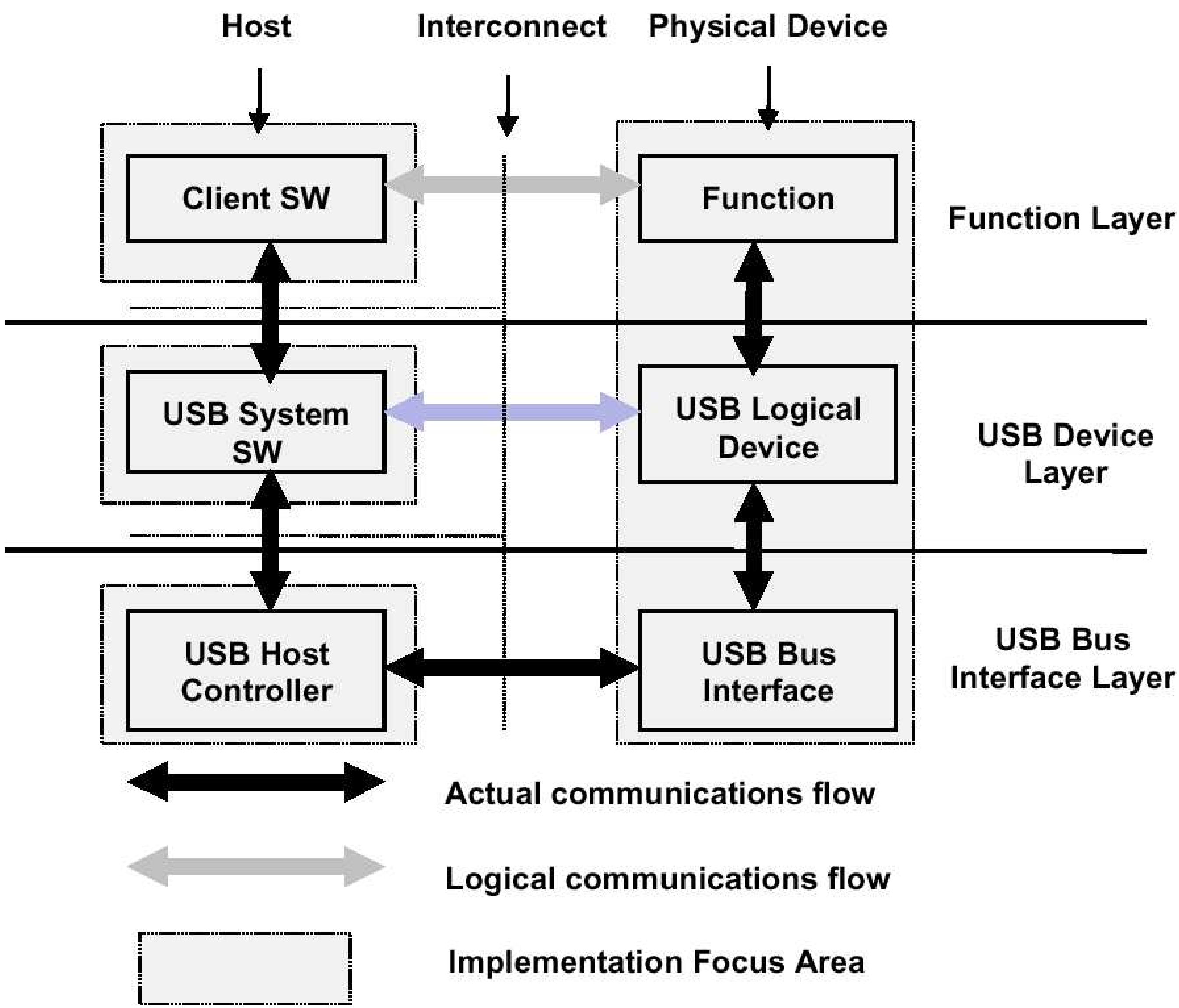
- Interrupt Data

  Timely, reliable delivery of data. Usually events.

- Isochronous Data

  For streaming real-time transfer: prenegotiated bandwidth and latency

Layered Architecture



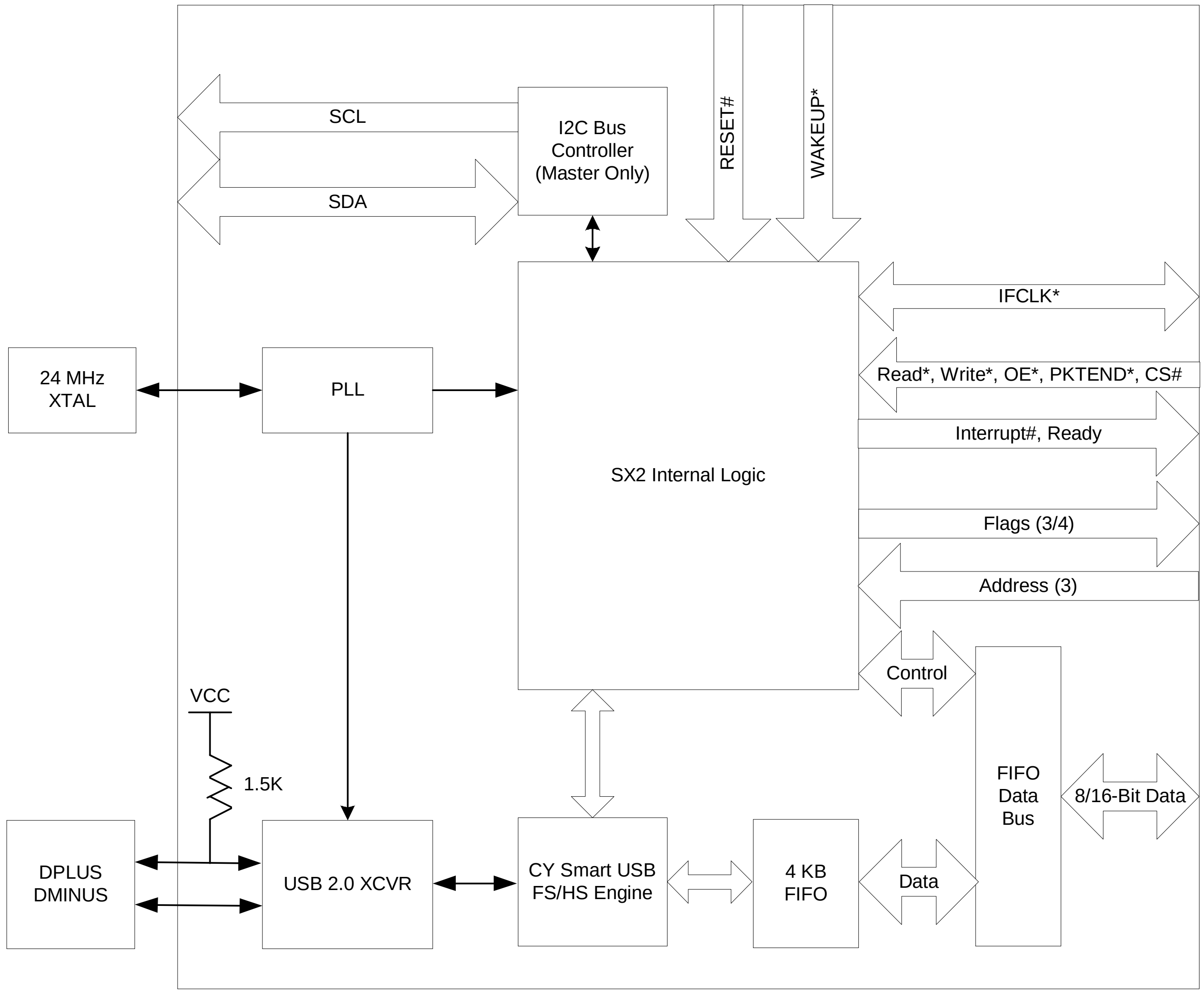
USB: Flash Card Device

```
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)
```

The CY7C68001 USB interface



The CY7C68001 USB interface

Operates as a peripheral (i.e., not a host)

Operates at 12 or 480 Mbps speeds

Control endpoint 0

Four other user-configurable endpoints

4 kB FIFO buffer

500 bytes of descriptor RAM (Vendor, Product)

I^2C bus interface for configuration from EEPROM

(Unused on the XSB board—processor must configure)

CY7C68001 software interface

Five memory locations: one for each FIFO, one for control registers

Internal registers written by first applying address to control register, then reading or writing data to control register.

33 different configuration registers, including 500-byte descriptor “register”