

# Serial Communications

## CSEE W4840

Prof. Stephen A. Edwards

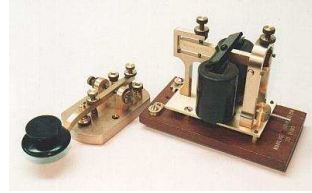
Columbia University

Serial Communications - p. 17

## 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	



Serial Communications - p. 27

## Later Serial Communication



Data Terminal Equipment



Data Communications Equipment

Serial Communications - p. 37

## RS-232

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

+12V } SPACE = 0  
+3V }

-3V } MARK = 1  
-12V }



Serial Communications - p. 47

## RS-232 Signals

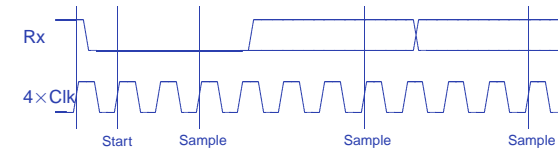


Signal DB-9 DTE ... Meaning

pin	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

Serial Communications - p. 57

## Receiving RS-232



Most UARTs actually use 16x clocks

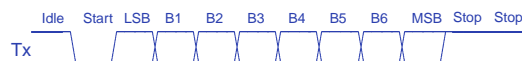
Serial Communications - p. 67

## Variants

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



Two stop bits:



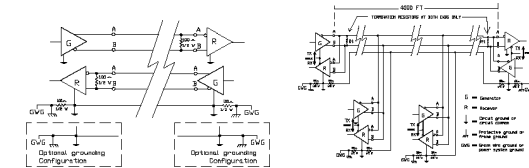
## Baud Rate

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

Serial Communications - p. 107

## 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)

Serial Communications - p. 117

## Status and Control Registers

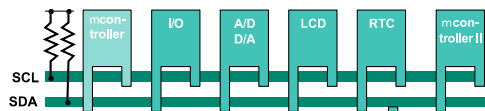
Bit	Status	Control
24	Parity Error	-
25	Framing Error	-
26	Overrun Error	-
27	Interrupts Enabled	Enable Interrupts
28	Tx buffer full	-
29	Tx buffer empty	-
30	Rx buffer full	Clear Rx buffer
31	Rx buffer non-empty	Clear Tx buffer

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

Serial Communications - p. 127

## The I<sup>2</sup>C Bus

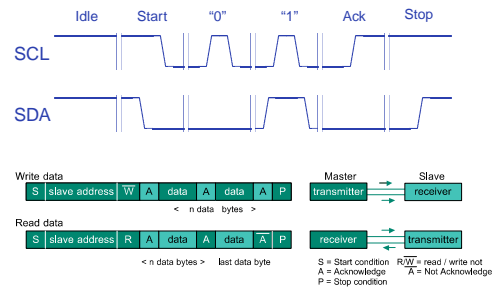
Philips invented the Inter-IC bus c. 1980 as a very cheap way to communicate slowly among chips  
E.g., good for setting control registers  
100, 400, and 3400 kHz bitrates



SCL: Clock, generated by a single master  
SDA: Data, controlled by either master or slaves

Serial Communications - p. 137

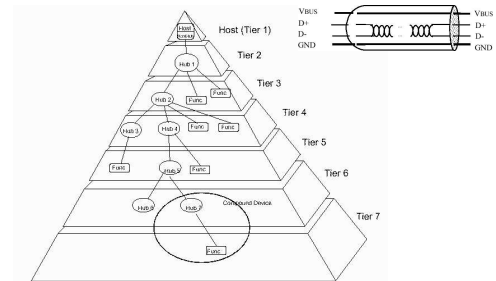
## I<sup>2</sup>C Bus Transaction



Serial Communications - p. 147

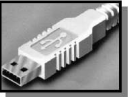
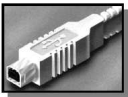


## USB: Universal Serial Bus

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



Serial Communications - p. 157

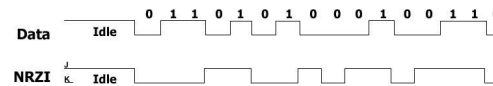
## USB Connectors

Series "A" Connectors	Series "B" Connectors
<p>Series "A" plugs are always oriented <b>upstream</b> towards the <i>Host System</i></p>  <p>"A" Plugs (From the USB Device)</p>	<p>Series "B" plugs are always oriented <b>downstream</b> towards the <i>USB Device</i></p>  <p>"B" Plugs (From the Host System)</p>
<p>"A" Receptacles (Downstream Output from the USB Host or Hub)</p> 	<p>"B" Receptacles (Upstream Input to the USB Device or Hub)</p> 

## 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).

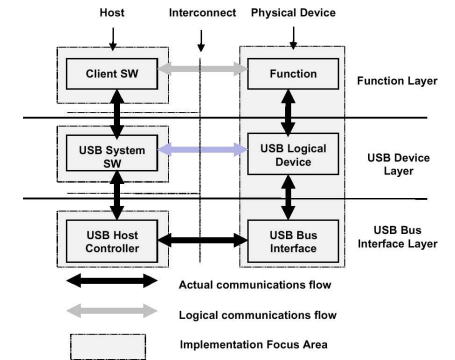
Serial Communications - p. 197

## 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

Serial Communications - p. 207

## Layered Architecture



Serial Communications - p. 217

## 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
    Synchron Type    none
  wMaxPacketSize     64
Endpoint Descriptor:
  bLength             7
  bDescriptorType    5
  bEndpointAddress   0x02  EP 2 OUT
  bmAttributes       2
    Transfer Type    Bulk
    Synchron Type    none
  wMaxPacketSize     64
Language IDs: (length=4)
  0409  English(US)
    
```

Serial Communications - p. 227

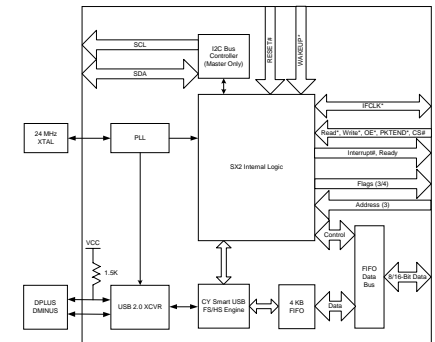
## USB: Mouse Device

```

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:
  bLength             7
  bDescriptorType    0x81  EP 1 IN
  bmAttributes       3
    Synchron Type    Interrupt
    Transfer Type    none
  wMaxPacketSize     4
  bInterval          10
Language IDs: (length=4)
  0409  English(US)
    
```

Serial Communications - p. 237

## The CY7C68001 USB interface



Serial Communications - p. 247

## 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<sup>2</sup>C 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”