Serial Communication

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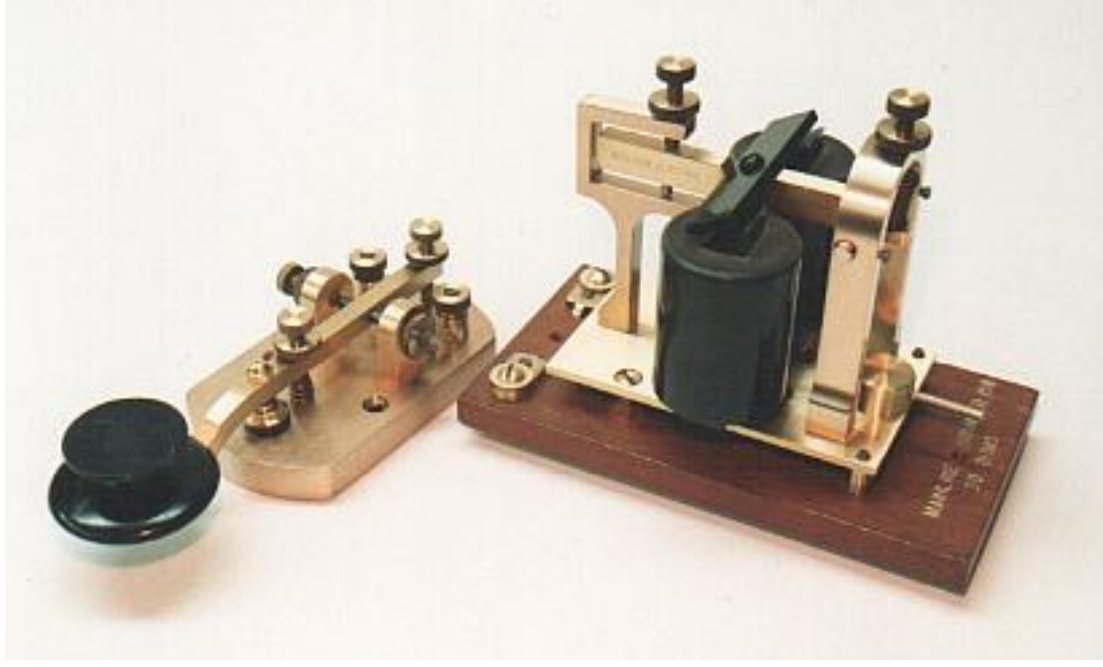
Spring 2012

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

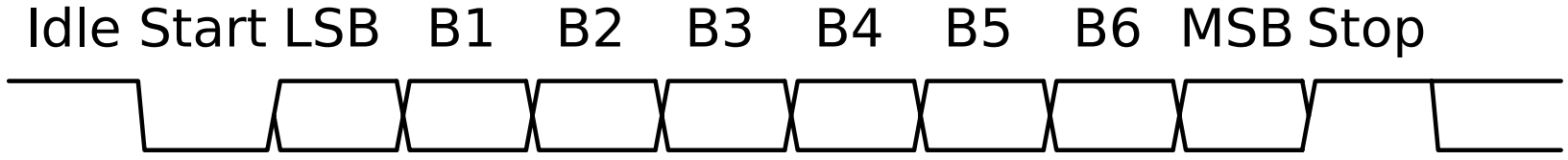
Data Communication Equipment

RS-232

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

+12V
+3V
} SPACE = 0

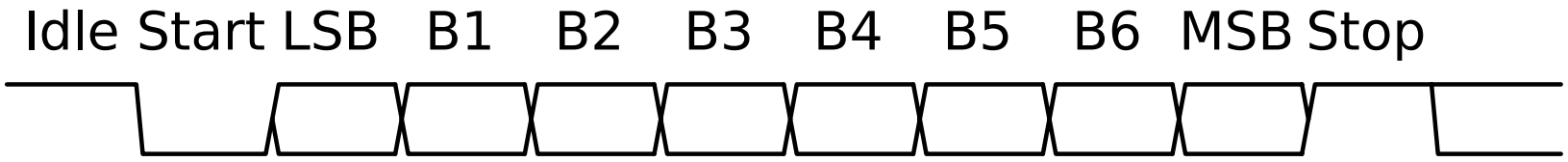
−3V
−12V
} MARK = 1

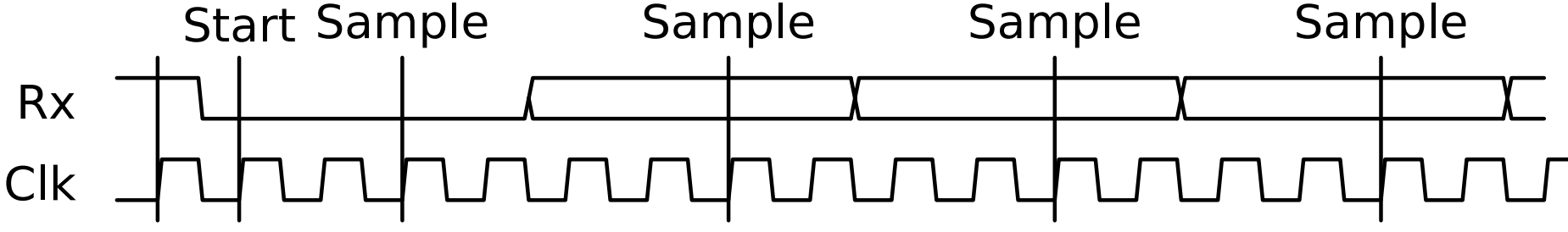


RS-232 Signals

Signal	 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

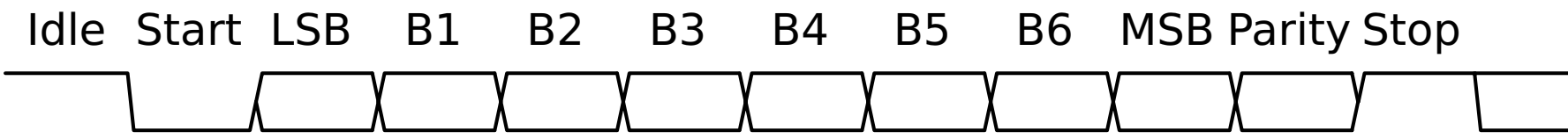




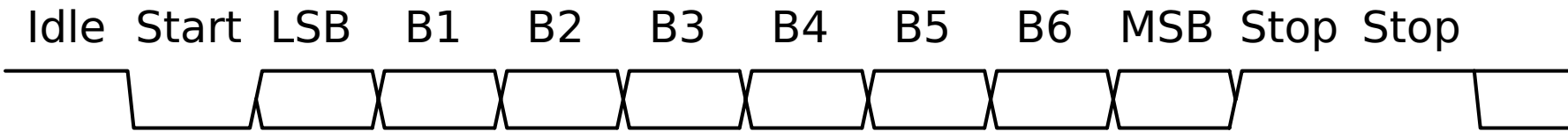
Most UARTs actually use 16× clocks

Variants

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



Two stop bits:



Baud Rate

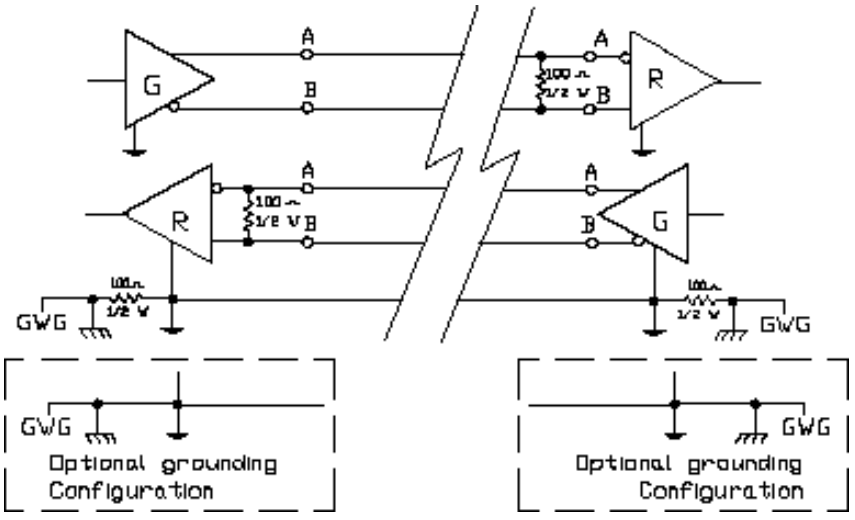
Baud: bits per second

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

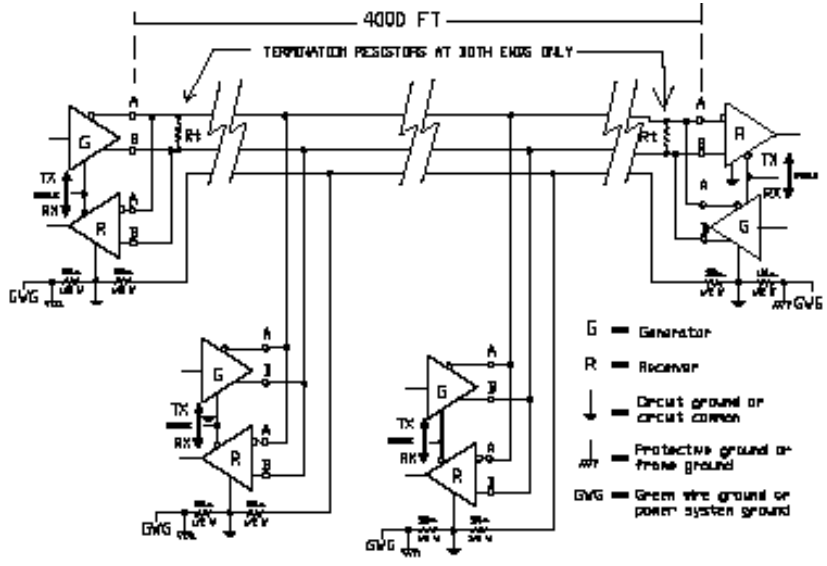
Physical Variants

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

RS-422: Differential signaling



RS-485: Bus-like

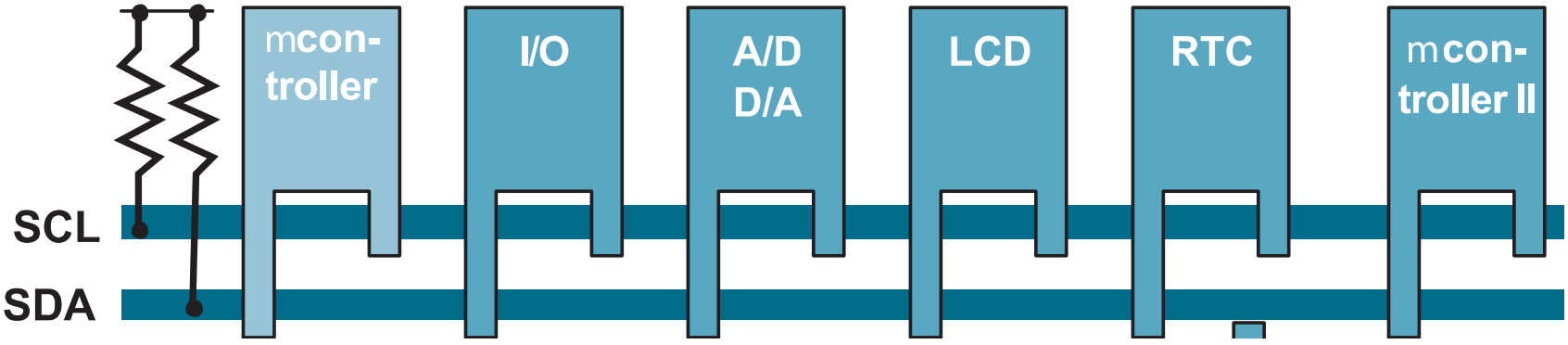


The I2C Bus

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

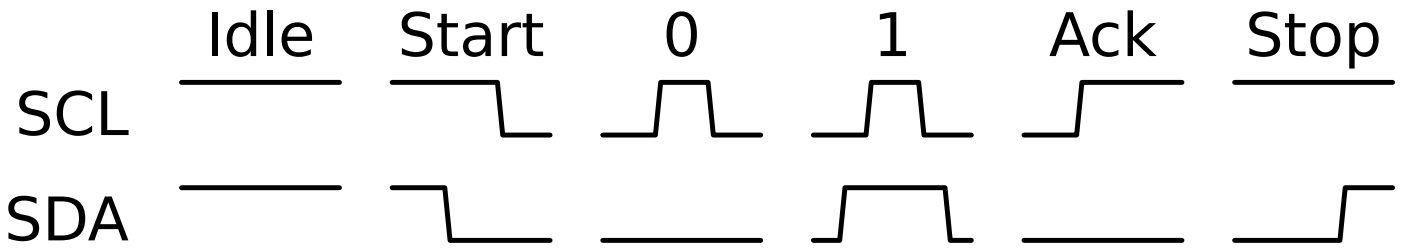
100, 400, and 3400 kHz bitrates



SCL: Clock, generated by a single master

SDA: Data, controlled by either master or slaves

I2C Bus Transaction



Write data

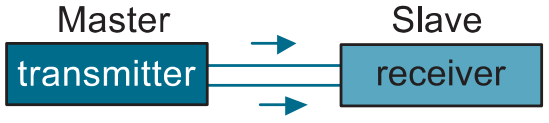
S	slave address	$\overline{W}$	A	data	A	data	A	P

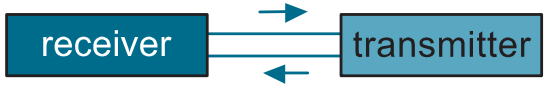
< n data bytes >

Read data

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

< n data bytes > last data byte





S = Start condition
A = Acknowledge
P = Stop condition

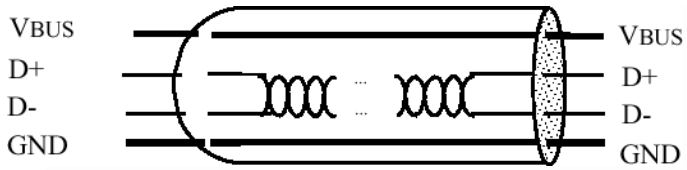
$R/\overline{W}$ = read / write not
$\overline{A}$ = Not Acknowledge

USB: Universal Serial Bus

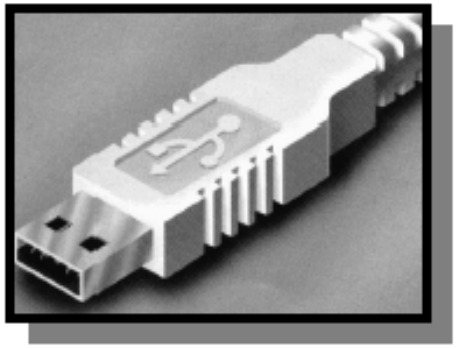
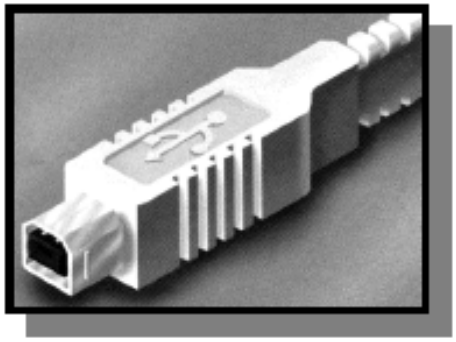
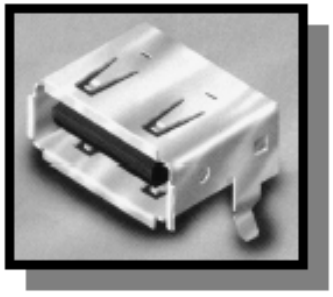
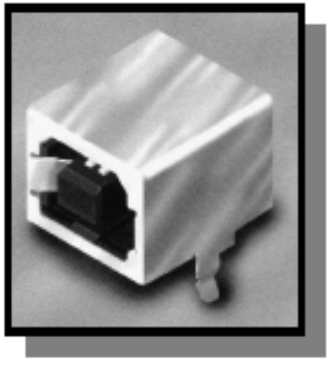
1.5 Mbps, 12 Mbps, and 480 Mbps (USB 2.0)

Point-to-point, differential, twisted pair

3–5m maximum cable length



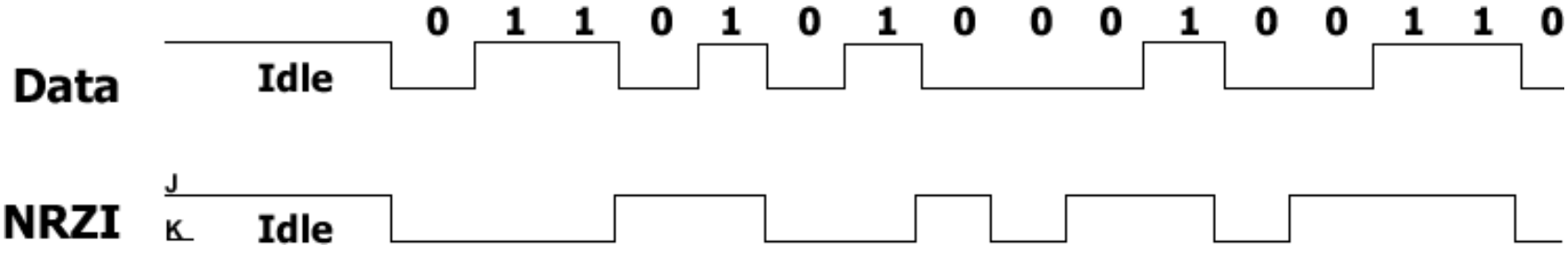
USB Connectors

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:

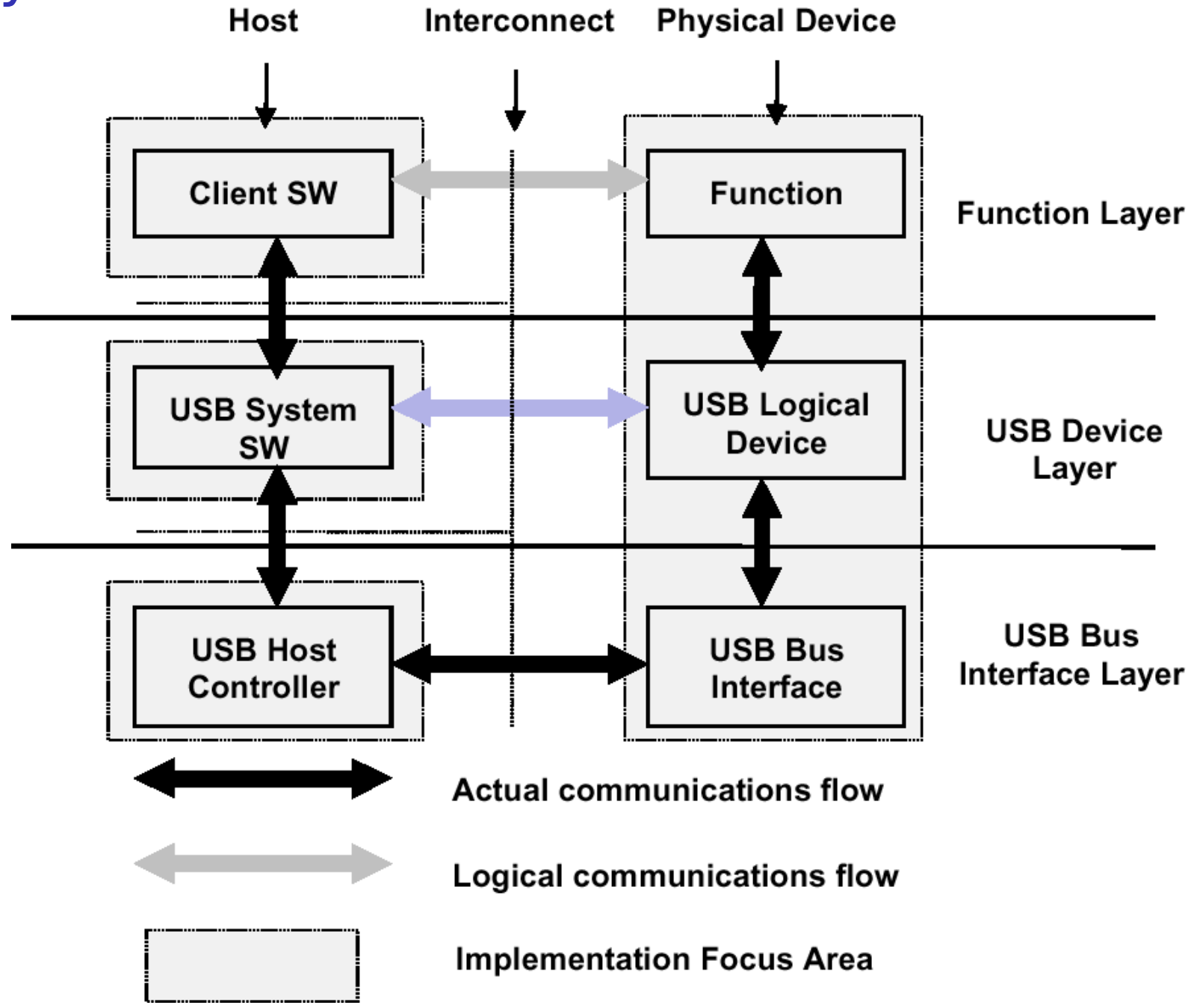
- “Token” packet from host requesting data
- Data packet from target
- Acknowledge from host

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



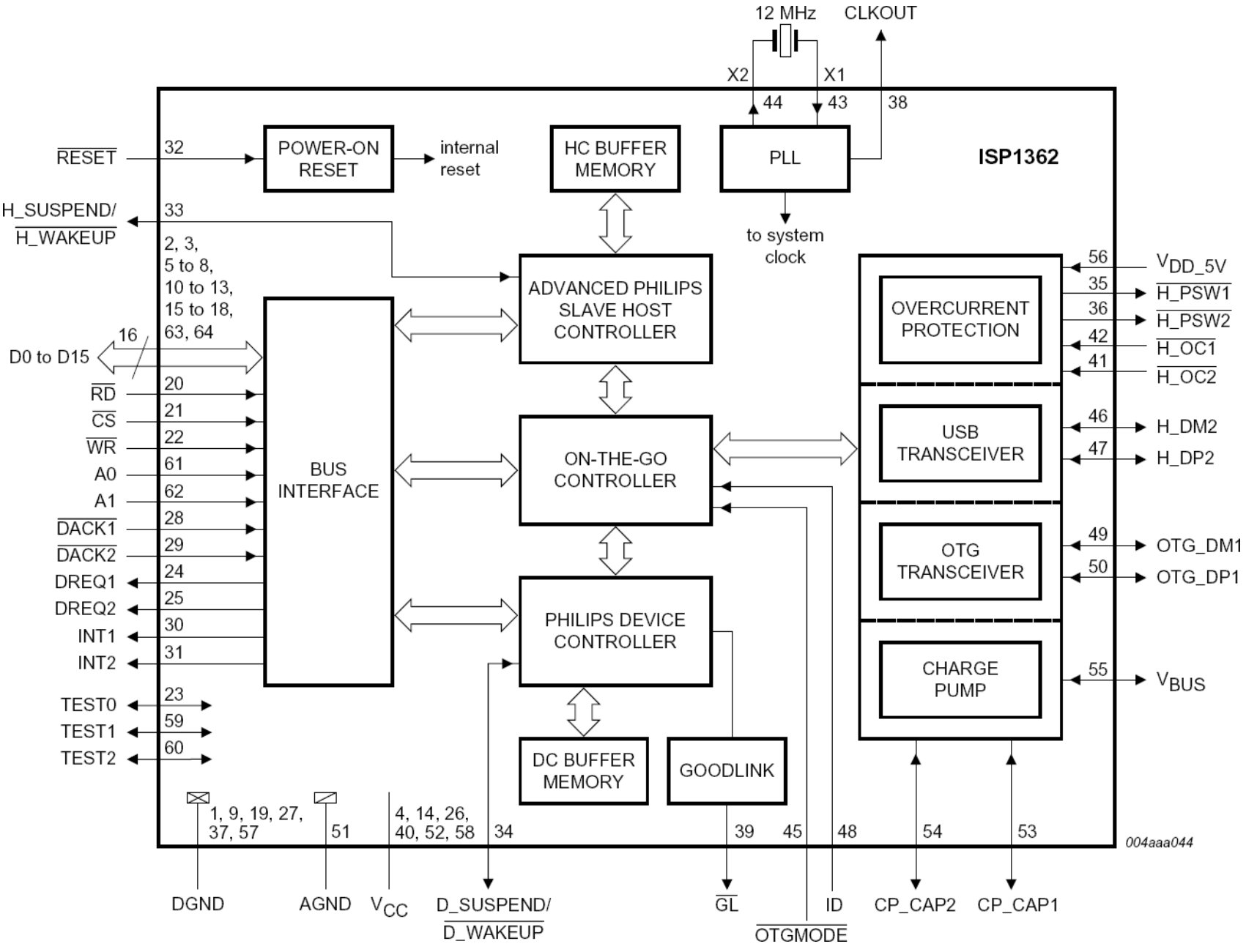
USB: Flash Card Device

```
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)
```

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