System Buses
Ch 3

Computer Function

Interconnection Structures

Bus Interconnection

PCI Bus

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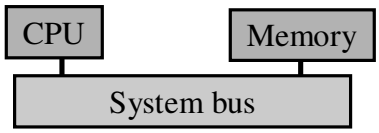
Computer Function

- von Neumann architecture
  - memory contains both instruction and data



- Fetch-Execute Cycle

(käskyn nouto ja suoritus sykli)

Figs 3.3, 3.9

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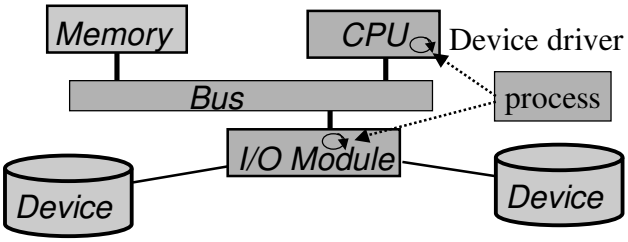
I/O control

- CPU executes instructions and with those instructions guides I/O modules
  - control and data registers in I/O modules
  - I/O modules give feedback to CPU with control and data registers, but only when CPU is reading them!



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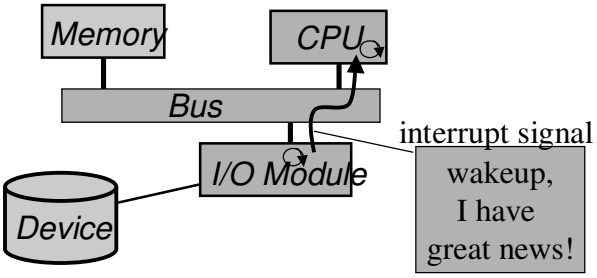
I/O Control

- Interrrupts allow I/O modules to give feedback to CPU even when CPU is doing something else



- DMA allows I/O modules to access memory without CPU's help

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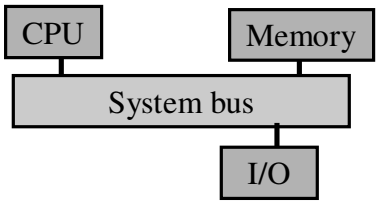
von Neumann Bottleneck

(von Neumann pullonkaula)



- All components communicate via system bus
- Each component has its own inputs/outputs

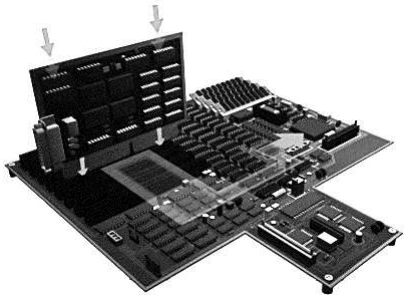
Fig. 3.15

  - System bus must support them all

Fig. 3.16

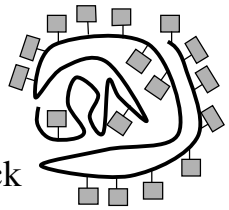
System Bus

- 50-100 lines (wires)
  - address
  - data
  - control
  - other: power, ground, clock



- Performance
  - bandwidth, how many bits per sec? (väyläkapasiteetti)
  - propagation delay? (päästä päähän viive)

Bus Configurations



- One bus alone
  - might be very long
    - large end-to-end signal time
  - serious von Neumann bottleneck
  - all devices use similar speeds
  - slowest device determines speed used
- Hierarchy of buses
  - can maximize speed for limited access
    - closer to CPU
  - lower speed general access I/O
    - further away from CPU

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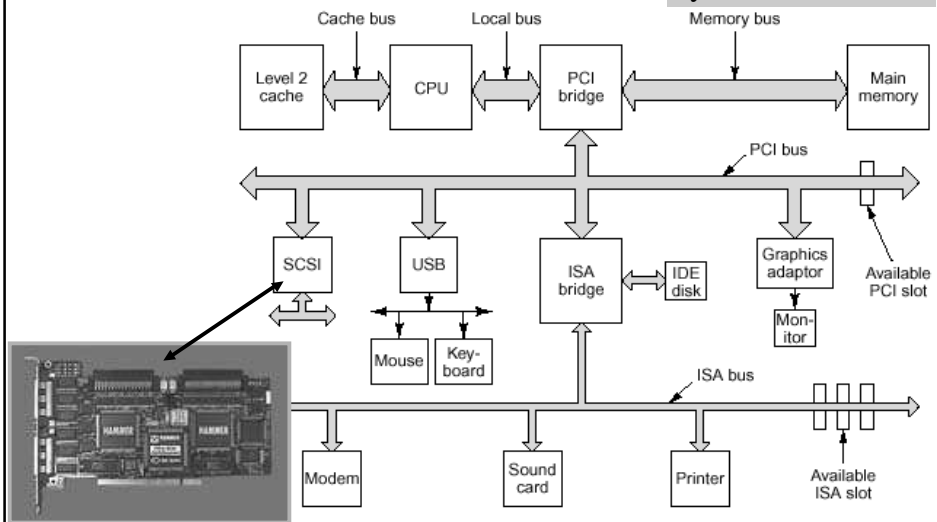
Hierarchy of Buses

Typical Pentium II system



PCI to SCSI bridge

(Tanenbaum, Structured Computer Organization, 4th Ed.)

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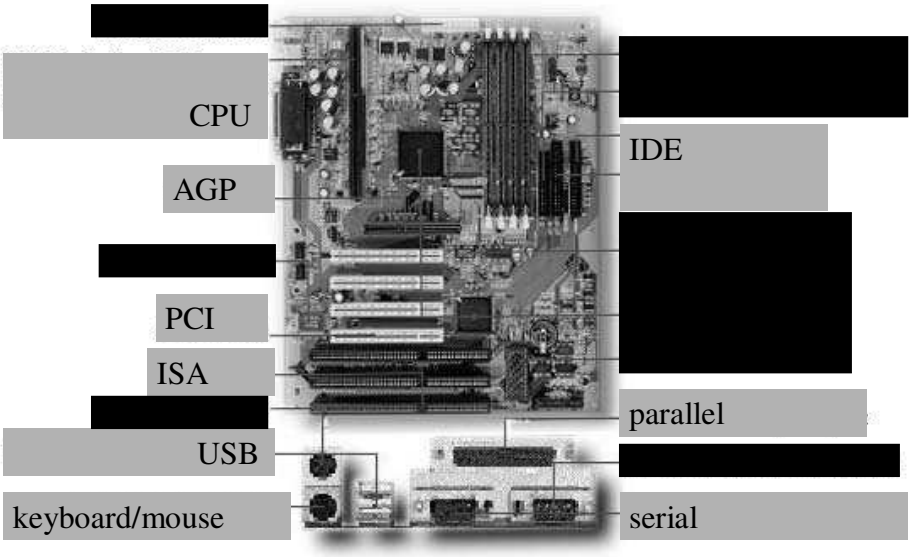
[LX6] - Pentium®II Processor Based Motherboard



http://www.abit-usa.com/english/product/index.htm

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Bus Design Features (3)

- Bus type
  - dedicated, multiplexed (aikavuorottelu)
- Arbitration method (vuoronvalinta)
  centralised, distributed (keskitetty, hajautettu)
  bus controller, arbiter (vuoronantaja)
- Timing
  synchronous
  asynchronous (asynkrooninen, epäsynkrooninen)

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Synchronous timing

- All same speed devices
- All synchronized with a clock signal
- Slowest device determines speed
- Can make assumptions on when some other device will do something, or how fast it will do it
  - 1 or 2 clock cycles to do it?

Fig. 3.19

(Fig. 3.19 (a) [Stal99])

Asynchronous timing

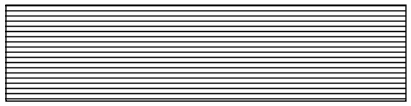
- No need to have same speed devices
- No synchronizing clock signal
- Timing determined only with change of signal levels
- Synchronize with signals (wires)
  - ”read”, ”write”, ”ack”, …
- Speed determined by devices in action
- Can ***not*** make assumptions on when some other device will do something, or how fast it will do it

Fig. 3.20

(Fig. 3.19 (b) [Stal99])

Bus Design Features (cont)

- Bus width
  - address, data



- Data transfer types
  - read, write
    - multiplexed & non-multiplexed operations
  - read-modify-write
    - E.g., for indivisible increments (multiproc. env.)
  - read-after-write
    - E.g., for check that write succeeds (multiproc. env.)
  - block
    - long delay for interrupt handling?

Fig. 3.21 (Fig. 3.20 [Stal99])

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Example Bus: Industry Standard Architecture (ISA, or PC-AT)

- Bus type: dedicated
- Arbitration method: single bus master
- Timing: asynchronous
  - own 8.33 MHz clock,
  - 15.9 MBps max data rate, 5.3 MBps in practice
- Bus width: address 32, data 16
- Data transfer type
  - read, write, read block, write block

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Example: Peripheral Component Interconnect (PCI) Bus

- Bus type: multiplexed
- Arbitration method: centralised arbiter
- Timing: synchronous, own 33 MHz clock
  - 2.122 Gbps (265 MBps) max data rate
- Bus width: address/data 32 (64), signal 17
- Data transfer type
  - read, write, read block, write block
- max 16 slots (devices)

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PCI Configurations

- Hierarchy Fig. 3.22 (Fig. 3.21 [Stal99])
- Bridge to internal/system bus allows them to be faster (with different bus protocol)
- Bridge to expansion buses allows them to slower (with different bus protocol)

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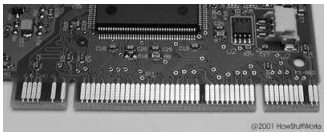
PCI card: 49 Mandatory Signals (6)



- 32 pins for address/data, time multiplexed
  - 1 parity pin
- 4 pins for command type/byte enable
  - E.g., 0110/1111 = memory read/all 4 bytes
- System pins (2): clock, reset
- Transaction timing & coordination pins (6)
- Arbitration pins (2 for each device) to PCI bus arbiter: REQ, GNT
- Error pins (2): parity, system

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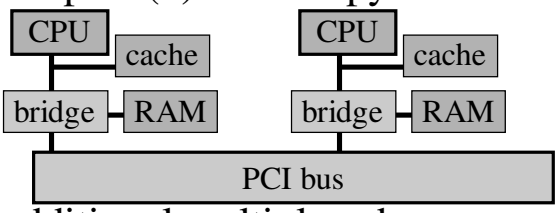
PCI Bus
41 Optional Signals (4)

- Request interrupt pins (4 pins for each dev)
- Cache support pins (2) for snoopy cache protocols



- 32 pins for additional multiplexed address/data
  - plus 7 control/parity pins
- 5 test pins

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PCI Bus Transaction (4)

- Bus activity is in separate transactions
- Each transaction preceded by arbitration

Fig. 3.24 (Fig. 3.23 [Stal99])

  - central arbiter (e.g., First-In-First-Out)
  - determines initiator/master for transaction
- Transaction is executed
- Bus is marked “ready” for next transaction

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PCI Transaction Types (5)

- Interrupt Acknowledge
  - READ interrupt parameter (e.g., subtype) for interrupt handler
- Special Cycle
  - broadcast message to many targets
- Configuration Read/Write
  - Read/Update (Write) device configuration data
- Dual Address Cycle
  - use 64 bit addresses in this transaction
- I/O or memory read/write (line, multiple)

PCI Read Transaction (no anim)

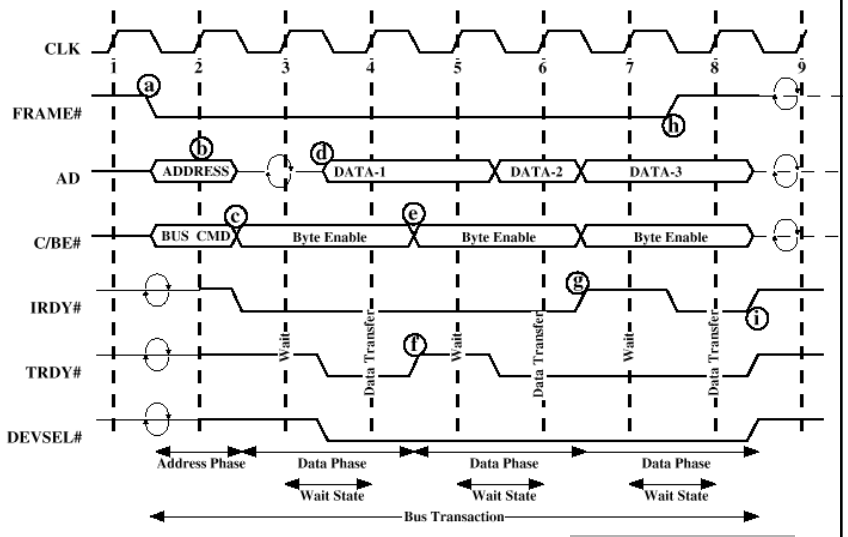
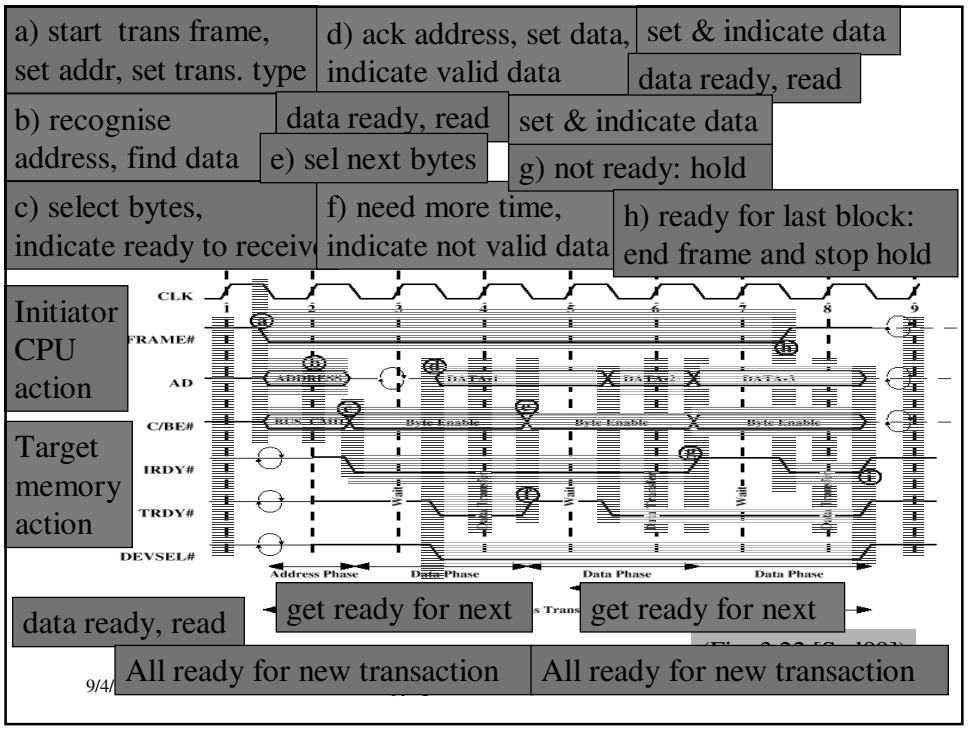


Fig. 3.23 (Fig. 3.22 [Stal99])



Arbitration: A and B want bus

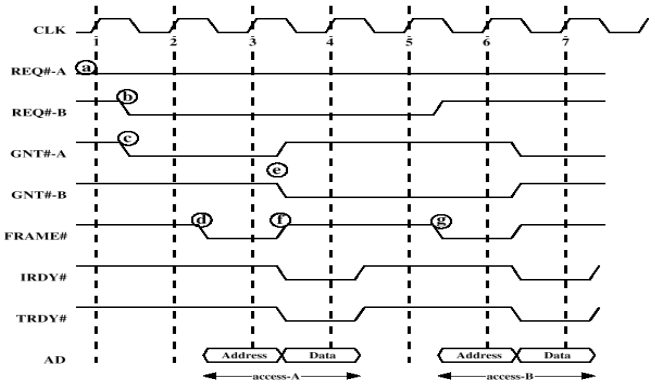


Fig. 3.25

Mostly just arbitration signals shown here (Fig. 3.24 [Stal99])

a) A wants bus

b) B wants bus

c) A granted bus knows that it has bus and bus is available

d) starts frame, requests for next transaction

Sees that both still want it

e) Grants bus to B for next trans.

f) marks last frame transfer, marks data ready

A's target reads data

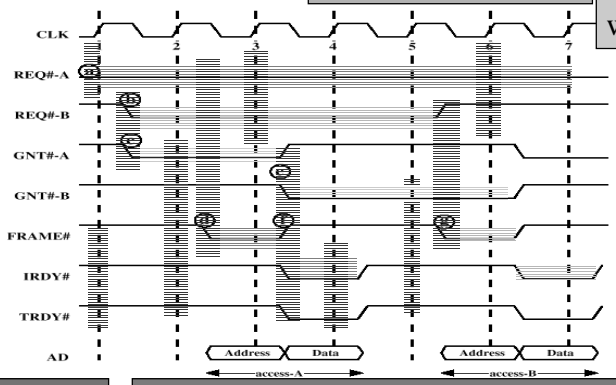
g) starts frame no more req.

Sees that only **A** wants it

A action

B action

Arbitrator action



All ready for new trans

All ready for new trans, granted for B, B knows that it has bus

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PCI Express: New Bus to Replace PCI

- Code name ”Arapahoe” or 3GIO
- Prevent bus bottleneck between fast CPU and memory of the future
- Arapahoe Work Group
  - Compaq, Dell, IBM, Intel and Microsoft
- Will replace PCI as industry standard
  - late 2003? low-end 2004? high-end 2005?
- PCI devices will work with PCI Express
- Speedup 30x as compared to std PCI
  - at least 8 GB/s vs. 264 MB/s
- Scalable capacity per device (pin count, speed)

http://www.pcisig.com

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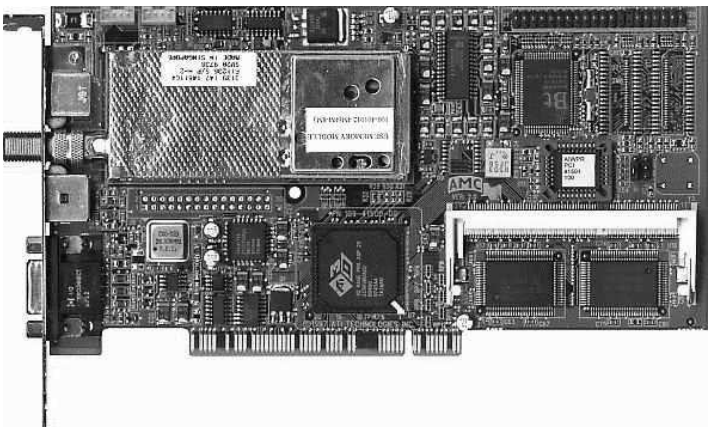
-- End of Chapter 3: System Buses --



(PCI card - connectors also on other side, some pins not used by this card)

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