COMP 3221

Microprocessors and Embedded Systems

Lectures 31: Memory and Bus Organisation - I

http://www.cse.unsw.edu.au/~cs3221

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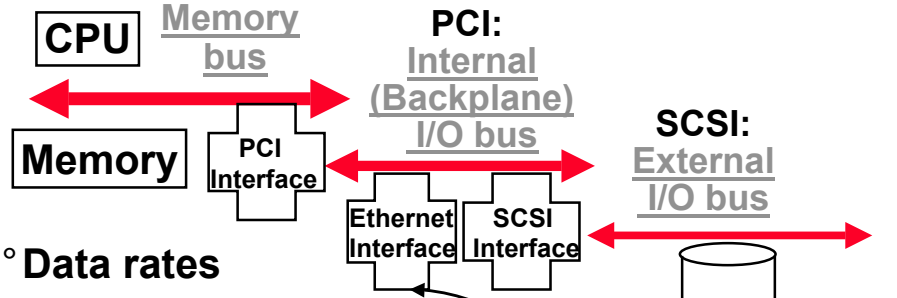
Overview

- Memory Interfacing
  - Memory Type
  - Memory Decoding
  - D-RAM Access
  - Making DRAM Access fast

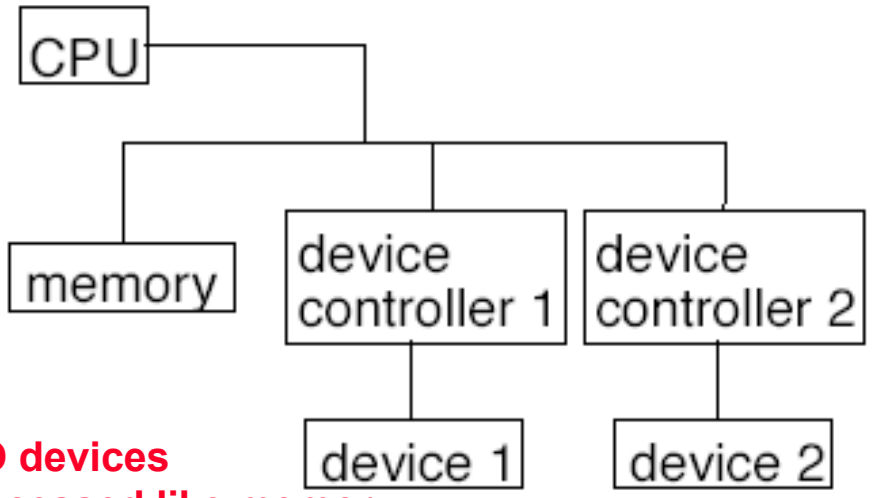
Review: Buses in a PC: Connect a few devices



- Data rates
  - Memory: 133 MHz, 8 bytes ⇒ 1064 MB/s (peak)
  - PCI: 33 MHz, 8 bytes wide ⇒ 264 MB/s (peak)
  - SCSI: "Ultra3" (80 MHz), "Wide" (2 bytes) ⇒ 160 MB/s (peak)

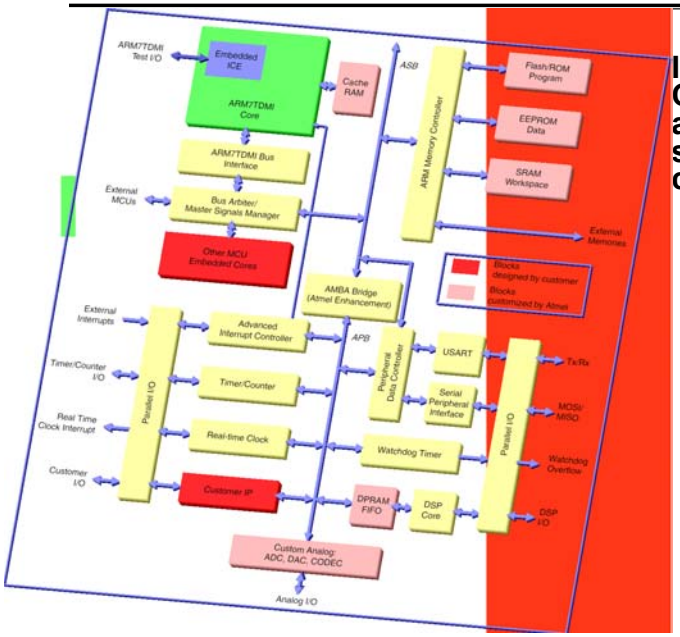
Ethernet: 12.5 MB/s (peak)

Review: Computers with Memory Mapped I/O



I/O devices Accessed like memory

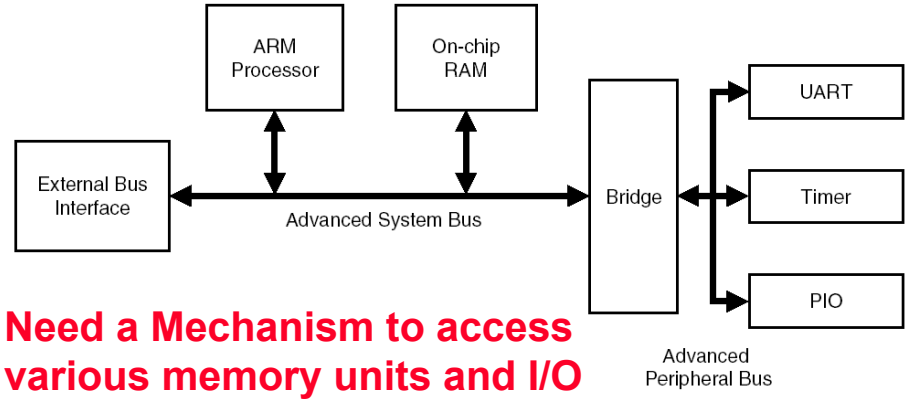
Big Picture: A System on a Chip



Integration of Core Processor and many sub-system micro-cells

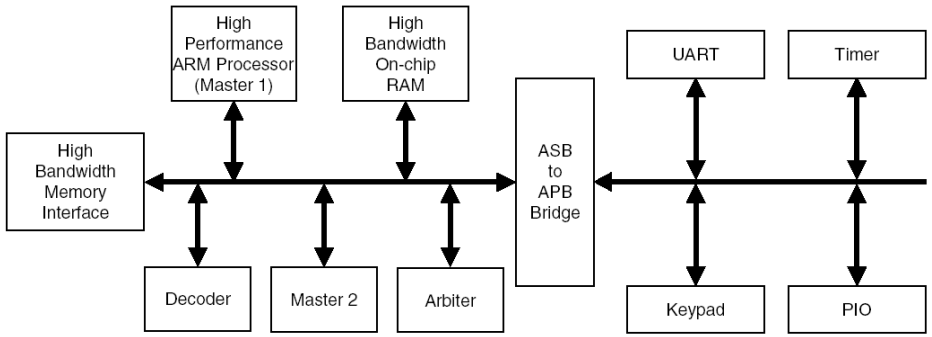
- **ARM7TDMI core**
- **Cache RAM**
- **Embedded Co-Processors**
- **External Mem Interface**
- **Low bandwidth I/O devices**
- **Timers**
- **I/O ports**

ARM System Architecture



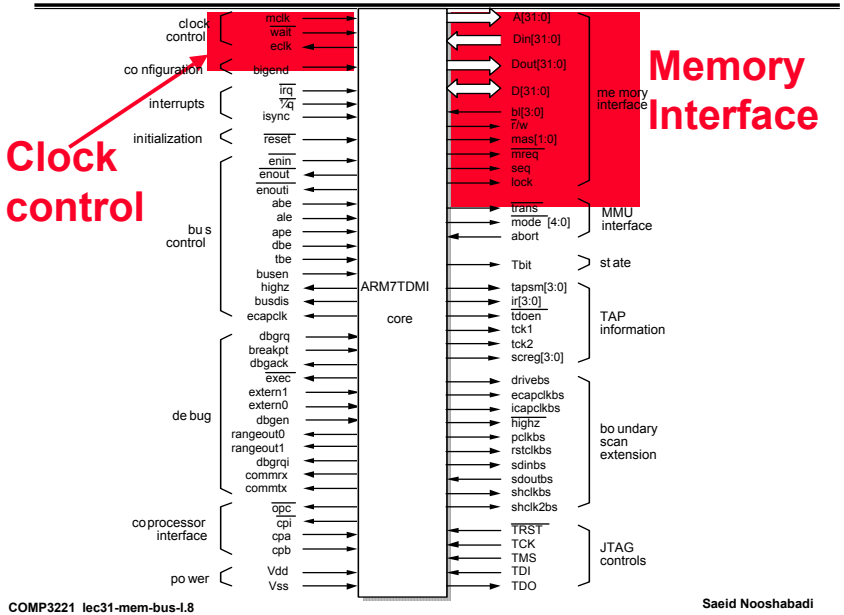
Need a Mechanism to access various memory units and I/O devices, uniquely, to avoid access conflicts

ARM System Architecture with Multiple Masters

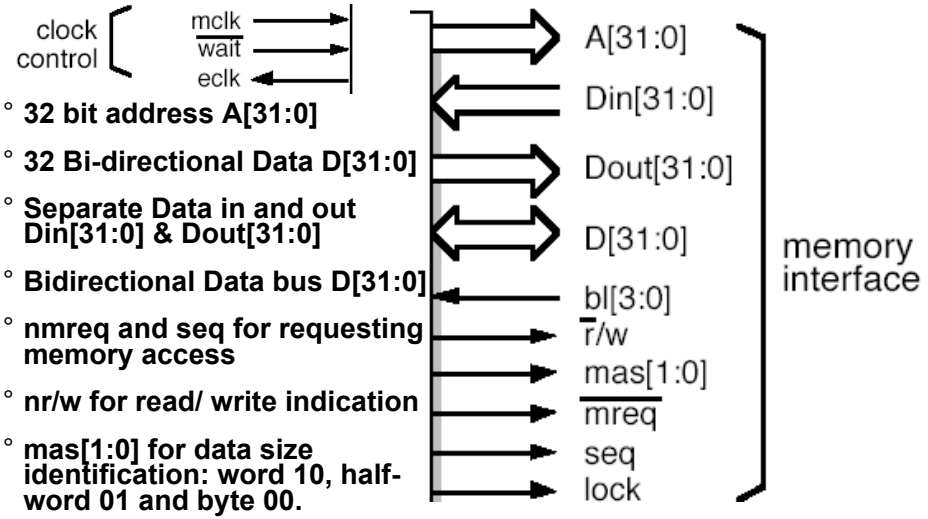


Need a Mechanism to allow various Processing units to access the Memory Bus without causing conflict

ARM Core Interface Signals



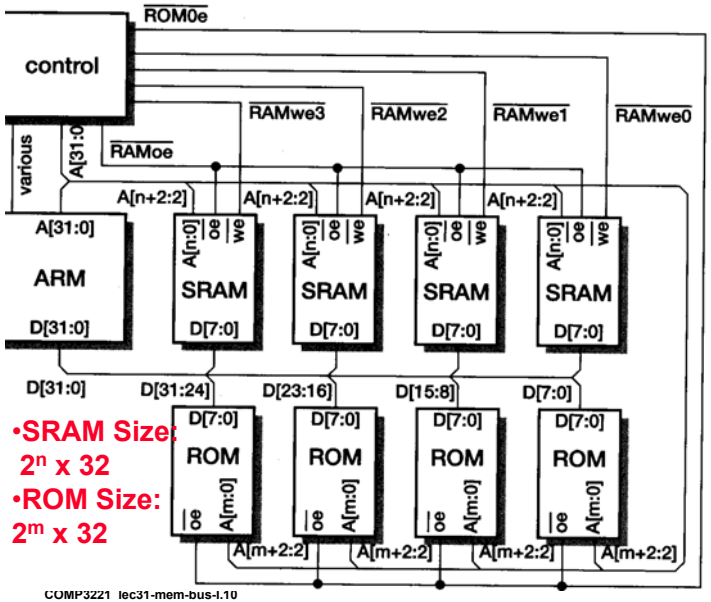
ARM Core Memory Interface Signals



- 32 bit address A[31:0]
- 32 Bi-directional Data D[31:0]
- Separate Data in and out Din[31:0] & Dout[31:0]
- Bidirectional Data bus D[31:0]
- nmreq and seq for requesting memory access
- nr/w for read/ write indication
- mas[1:0] for data size identification: word 10, half-word 01 and byte 00.
- All activities controlled by mclk.

- Internal clock is mclk AND wait

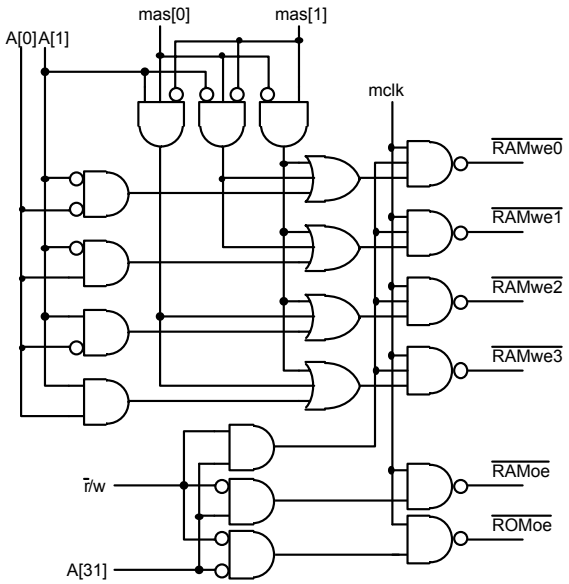
Simple Memory Interface



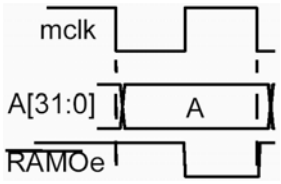
- 4 SRAMs
  - write enabled separately
  - Read enabled together
- 4 ROMs
  - No write enable
  - Read enabled together

- SRAM Size: 2^n x 32
- ROM Size: 2^m x 32

Simple Memory Decoder Control

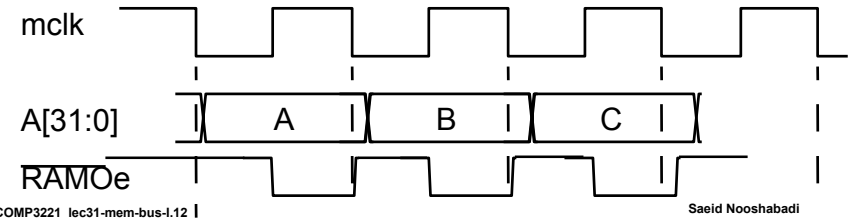


- Controls the Activation of RAM and ROM
- a[31]: 0 → ROM
  a[31]: 1 → RAM
- It controls the byte write enables during write
  - mas[1:0]: 00 Byte, 01 H-word, 10 Word
- It ensures that data is ready before processor continues.



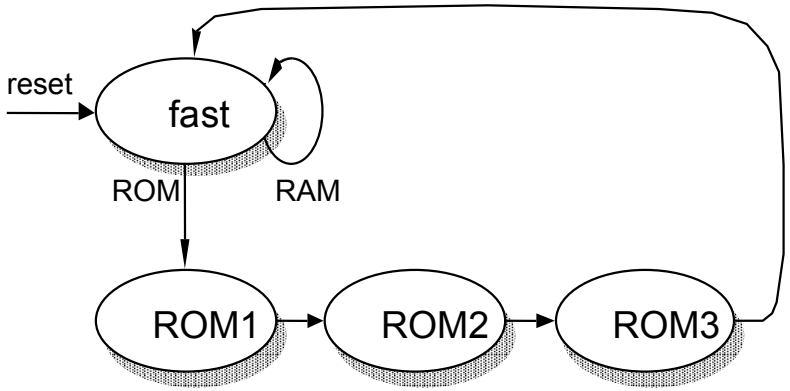
SRAM/ROM Memory Timing

- Address should be stable during the falling edge
- SRAM is fast, ROM is slow
  - ROM needs more time. Slows the system
  - Solutions?
    - Slow down the MCLK clock; loose performance
    - Use Wait states; more complex control

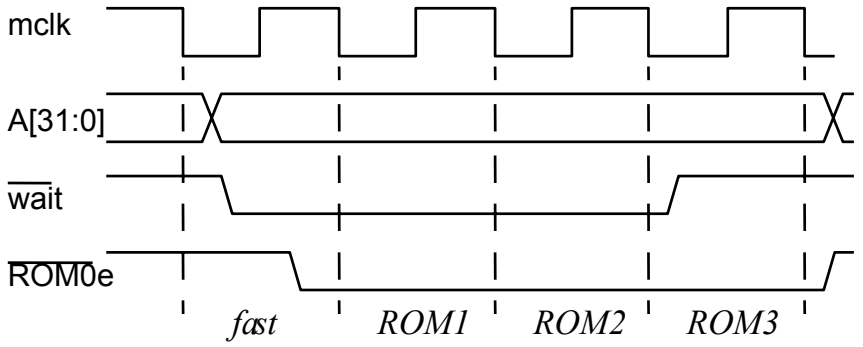


ROM Wait Control State Transition

- ROM access requires 4 clock cycles
- RAM access is fast



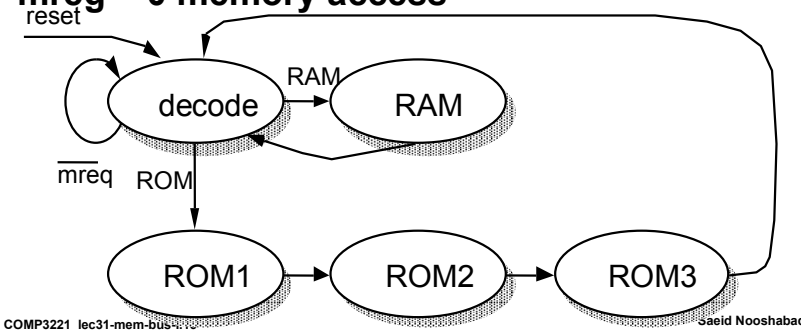
Timing Diagram for for ROM Wait States



Improving Performance

- Processor internal operations cycles do not need access to memory
  - Mem. Access is much slower than internal operations.
  - Use wait states for mem Accesses
- mreq = 1 internal operation
- mreg = 0 memory access

Internal Operations can run at max speed

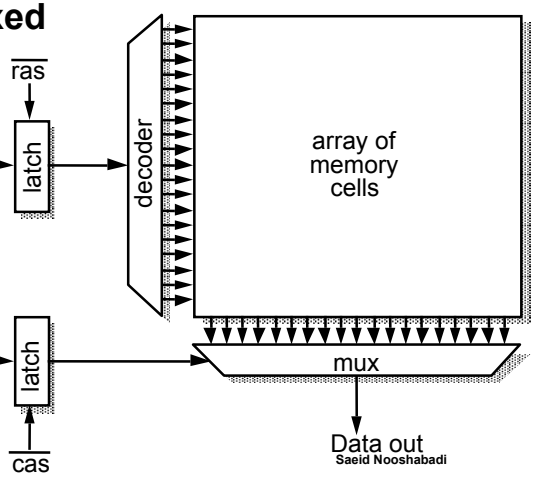


DRAM Interface

- Dynamic RAM Features:
  - much cheaper than SRAM
  - more capacity than SRAM
  - slower than SRAM
- Widely used in Computer Systems

DRAM Organisation

- Two dimensional matrix
- Bits are accesses by:
  - Accepting row and column addresses down the same multiplexed address bus
  - First Row address is presented and latched by ras signal
  - Next column address is presented and latched by cas signal

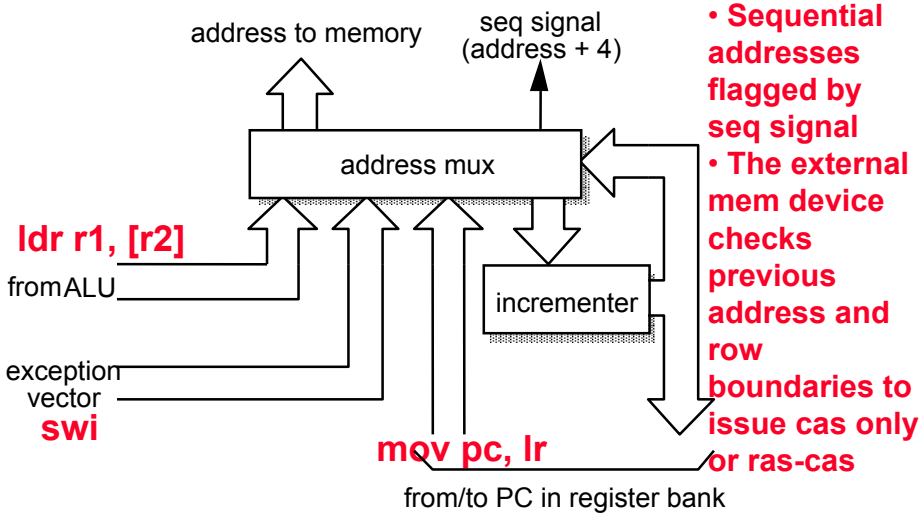


Making DRAM Access Fast

- Accessing data in the same row using cas-only access is 2 – 3 times faster
  - cas-only access does not activate the cell matrix
  - If next accesses is within the same row, a new column address may be presented just by applying a cas-only access.
- Fact: Most processor addresses are sequential (75%)
- If we had a way of knowing that that the next address is sequential with respect with the current address (current address + 4), then we could only assert cas and make DRAM access fast
- Difficulty?
  - Detecting early in memory access cycle that the next address is in the same row.

ARM Solution to cas-only Access

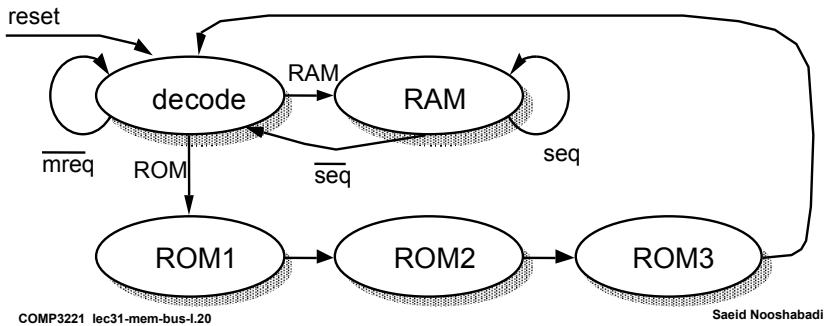
- ARM address register Instruction:
  - 75% of next addresses are current address +4.



- Sequential addresses flagged by seq signal
- The external mem device checks previous address and row boundaries to issue cas only or ras-cas

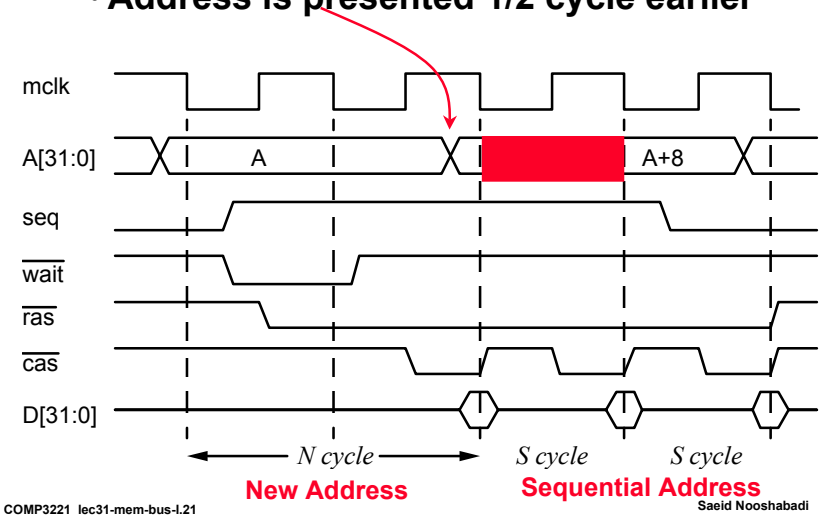
Revised State Transition Diagram

- seq = 1: sequential address
- seq = 0: non-sequential
- mreq = 1 internal operation
- mreg = 0 memory access



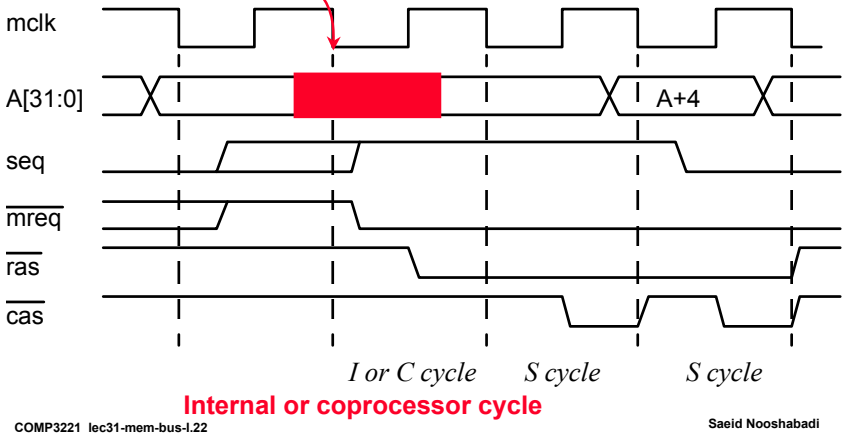
DRAM Timing Diagram

° Notice the pipelined memory access
  • Address is presented 1/2 cycle earlier

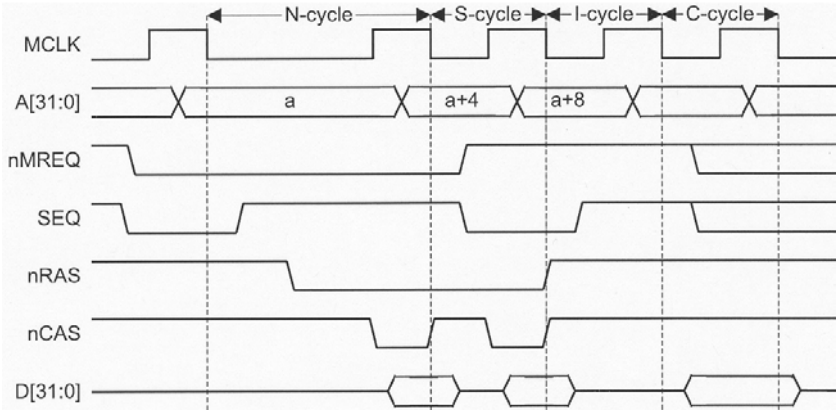


DRAM Timing Diagram after an Internal Cycle

° During internal operations cycles, a memory access cycle can be set up in advance.
  • This eliminates the wait (New Cycle) state



Memory Access Timing Summary



° Notice the pipelined memory access
  • Address is presented 1/2 cycle earlier

Reading Material

° Steve Furber: ARM System On-Chip; 2nd Ed, Addison-Wesley, 2000, ISBN: 0-201-67519-6. Chapter 8.

Conclusion

- Memory interfacing can degrade performance
- Can improve performance by increasing the clock frequency and allocating differing clock cycles for each memory access type
- cas-only accesses in DRAM are 2 to 3 times faster than ras – cas accesses.