Chapter 08: The Memory System

Lesson 12: Memory Interleaving
Objective

- Learn memory interleaving method for the pipeline like access
Interleaving (Pipeline)
Improving Performance by Banking and Interleaving

- Interleaving— for facilitating the simultaneous accesses to the memory system
Interleaving Like Pipeline

• Memory systems can be pipelined in the same way that processors are pipelined, allowing operations to overlap execution to improve throughput
• Interleaving permits accesses like instructions in a pipeline
Interleaving Example 1

- Assume that first vertical column activates by chip-enable 0, second by chip-enable 1, and so on.
- \( A_j \) to \( A_{n-1} \) are the address bus signals directly connected to the processor address bus.
- \( A0 \) and \( A1 \) select a column out of the four columns.
- Each byte sequentially one after one read or written in interleaving of the four banks.
Example 1 of interleaved memory

• Memory system with a latency of 40 ns that transfers 1 byte per operation
• Pipelined to allow 4 operations to overlap execution (assume no pipelining overhead)
Solution for bandwidth

- Dividing the latency of 40 ns by the number of overlapped operations (4 gives a rate of 1 operation per 10 ns as the throughput of the memory system.
- At 1 byte of data per operation, this gives a bandwidth of $10^8$ bytes/s.
Banking (parallel) plus Interleaving (Pipeline)
Banking plus Interleaving

• Instead of two lower address bits two other address bits could be used to select a bank
• Generally, relatively low-order address bits are used to select the bank, so that references to sequential memory addresses go to different banks
• Lowest order bits used for interleaving (pipeline like access)
Interleaving Example 2

- Interleaving of data of addresses $A_2$ to $A_{j-1}$, and $A_{n+j}$ and $A_{m-1}$ select a vertical column bank when four banks simultaneously parallel accessed.

- Each word sequentially one after one read or written using horizontally placed set of 4 RAMs and there is simultaneous access of the four vertical banks.
Interleaving pipelined access from 4 RAMs and parallel access from 4 vertical banks and
Example 2 banking plus interleaving

• Assume—A memory system has four banks, each of which has a latency of 100 ns and is pipelined to allow 8 operations to overlap execution

• Each bank returns 4 bytes of data in response to a memory request
Solution for the peak throughput and peak bandwidth of this system

• Each bank has a latency of 100 ns and can pipeline 8 operations
• Therefore, the throughput of each bank is 1 operation every 100 ns/8 = 12.5 ns, or 80,000,000 operations/s
• Since there are 4 banks, the peak throughput of the memory system is 4 × 80,000,000 = 320,000,000 operations/s
Solution for the peak throughput and peak bandwidth of this system

- With each memory operation returning 4 bytes of data, this gives a peak bandwidth of $4 \times 320,000,000 = 1,280,000,000$ bytes/s

- Peak bandwidth computations assumes no idle time between one and other subsequent accesses after the first
Summary
We learnt

- Memory bank concept for the parallel access
- Memory interleaving method for the pipeline like access
End of Lesson 12 on Memory Interleaving