

# Computer Architecture – tutorial 4

## Context, Objectives and Organization

This worksheet covers the material from Lecture 6 on Caches. The goal of the quantitative exercises in this tutorial is to familiarize you with quantitative analysis of caches (E1) and to investigate the tradeoffs between write-through and write-back caches (E2 and E3).

### E1: individual – 15 min

#### *Problem*

Assume we have a computer where the CPI is 1.0 when all memory accesses (including data and instruction accesses) hit in the cache. The cache is a unified (data + instruction) cache of size 256 KB, 4-way set associative, with a block size of 64 bytes. The data accesses (loads and stores) constitute 50% of the instructions. The unified cache has a miss penalty of 25 clock cycles and a miss rate of 2%. Assume 32 bit instruction and data addresses.

- What is the tag size for the cache?
- How much faster would the computer be if all memory accesses were cache hits?

### E2: groups of 2 – 15 min

#### *Problem*

You purchased an Acme computer with the following features:

- 95% of all memory accesses are found in the cache.
- Each cache block is two words, and the whole block is read on any miss.
- The processor sends references to its cache at the rate of  $10^9$  words per second.
- 25% of those references are writes.
- Assume that the memory system can support  $10^9$  words per second, reads or writes.
- The bus reads or writes a single word at a time (the memory system cannot read or write two words at once).
- Assume at any one time, 30% of the blocks in the cache have been modified.
- The cache uses write allocate on a write miss.

You are considering adding a peripheral to the system, and you want to know how much of the memory system bandwidth is already used. Calculate the percentage of memory system bandwidth used on the average in the two cases below. Be sure to state your assumptions.

- a. The cache is write through.
- b. The cache is write back.

### **E3: groups of 2 – 15 min**

#### *Problem*

One difference between a write-through cache and a write-back cache can be in the time it takes to write. During the first cycle, we detect whether a hit will occur, and during the second (assuming a hit) we actually write the data. Let's assume that 50% of the blocks are dirty for a write-back cache. For this question, assume that the write buffer for the write through will never stall the CPU (no penalty). Assume a cache read hit takes 1 clock cycle, the cache miss penalty is 50 clock cycles, and a block write from the cache to main memory takes 50 clock cycles. Finally, assume the instruction cache miss rate is 0.5% and the data cache miss rate is 1%. Assuming that on average 26% and 9% of instructions in the workload are loads and stores, respectively, estimate the performance of a write-through cache with a two-cycle write versus a write-back cache with a two-cycle write.

*Vijay Nagarajan 2012, thanks to Nigel Topham and Marcelo Cintra*