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# Homework 1

Computer Organization and Design: The Hardware/Software Interface
Chapter 1: Problem

**1.3 [2] <§1.3>** Describe the steps that transform a program written in a high-level language such as C into a representation that is directly executed by a computer processor.

There are four main parts to transforming high level C code into a form that can be executed by the computer. First, a preprocessor gathers the code included in header files and translates the source code that references content in those header files. That extended source code is then translated to assembly language for that specific platform.That assembly code is then translated to much simpler machine code, then finally linked with other library functions to produce an executable file/.

**1.4 [2] <§1.4>** Assume a color display using 8 bits for each of the primary colors (red, green, blue) per pixel and a frame size of 1280 × 1024.
a. What is the minimum size in bytes of the frame buffer to store a frame?

8 bits per color = 1 byte per color
3 colors = 3 bytes

3 bytes * 1280 pixels * 1024 pixels = **3,932,160 bytes minimum to store a frame**

b. How long would it take, at a minimum, for the frame to be sent over a 100 Mbit/s network?

3,932,160 bytes * 8 = 31,457,280 bits

31,457,280 bits / 100*(10^6) bits/second = **0.314 seconds to send one frame**

**1.5 [4] <§1.6>** Consider three different processors P1, P2, and P3 executing the same instruction set. P1 has a 3 GHz clock rate and a CPI of 1.5. P2 has a 2.5 GHz clock rate and a CPI of 1.0. P3 has a 4.0 GHz clock rate and has a CPI of 2.2.
a. Which processor has the highest performance expressed in instructions per second?

Clock rate = Cycles per second
CPI = cycles per instruction

Instructions per second = Clock rate / CPI

P1 = 3GHz / 1.5 = 2x10^9 instructions per second
**P2 = 2.5GHz / 1.0 = 2.5x10^9 instructions per second**
P3 = 4.0GHz / 2.2 = 1.81x10^9 instructions per second

b. If the processors each execute a program in 10 seconds, find the number of cycles and the number of instructions.

P1 = 2x10^9 instructions per second * 10s = **20x10^9 instructions**
P2 = 2.5x10^9 instructions per second * 10s = **25x10^9 instructions**
P3 = 1.81x10^9 instructions per second * 10s = **18.1x10^9 instructions**

P1 = 3GHz * 10s = **30x10^9 cycles**
P2 = 2.5GHz * 10s = **25x10^9 cycles**
P3 = 4.0GHz * 10s = **40x10^9 cycles**

c. We are trying to reduce the execution time by 30% but this leads to an increase of 20% in the CPI. What clock rate should we have to get this time reduction?

execution time, assumed 10s*0.7 = 7s
instructions = see part b
cpi = cycles per instruction = y*1.2
clock rate = cycles per second = cpi * instructions / seconds

P1 = (1.5 * 1.2 * 20x10^9 instructions) / 7s = **5.14GHz**
P2 = (1.0 * 1.2 * 25x10^9 instructions) /7s = **4.28GHz**
P3 = (2.2 * 1.2 * 18.1x10^9 instructions) / 7s = **6.82GHz**

**1.6 [20] <§1.6>** Consider two different implementations of the same instruction set architecture. The instructions can be divided into four classes according to their CPI (class A, B, C, and D). P1 with a clock rate of 2.5 GHz and CPIs of 1, 2, 3, and 3, and P2 with a clock rate of 3 GHz and CPIs of 2, 2, 2, and 2.
Given a program with a dynamic instruction count of 1.0E6 instructions divided into classes as follows: 10% class A, 20% class B, 50% class C, and 20% class D, which implementation is faster?
a. What is the global CPI for each implementation?

b. Find the clock cycles required in both cases.

1.7 [15] <§1.6> Compilers can have a profound impact on the performance of an application. Assume that for a program, compiler A results in a dynamic instruction count of 1.0E9 and has an execution time of 1.1 s, while compiler B

results in a dynamic instruction count of 1.2E9 and an execution time of 1.5 s.
a. Find the average CPI for each program given that the processor has a clock cycle time of 1 ns.
b. Assume the compiled programs run on two different processors. If the execution times on the two processors are the same, how much faster is the clock of the processor running compiler A's code versus the clock of the processor running compiler B's code?
c. A new compiler is developed that uses only 6.0E8 instructions and has an average CPI of 1.1. What is the speedup of using this new compiler versus using compiler A or B on the original processor?

1.11
11 parts

1.12
4 parts