Homework 1

**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? 3 points

**b.** If the processors each execute a program in 10 seconds, find the number of cycles and the number of instructions. 3 points

**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? 3 points

**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? 3 points

**b.** Find the clock cycles required in both cases. 3 points

**1.14** Assume a program requires the execution of 50 × 106 FP instructions, 110 × 106 INT instructions, 80 × 106 L/S instructions, and 16 × 106 branch instructions. The CPI for each type of instruction is 1, 1, 4, and 2, respectively. Assume that the processor has a 2 GHz clock rate.

**1.14.1** [10] <§1.10> By how much must we improve the CPI of FP instructions if we want the program to run two times faster? 3 points

**1.14.2** [10] <§1.10> By how much must we improve the CPI of L/S instructions if we want the program to run two times faster? 3 points

**1.14.3** [5] <§1.10> By how much is the execution time of the program improved if the CPI of INT and FP instructions is reduced by 40% and the CPI of L/S and Branch is reduced by 30%? 3 points

1. Derive the equation for U2T(x), draw the diagram to show the relationship between these two data types. (10 points)

2. If we have an n-digit unsigned numeral $d_{n-1}d_{n-2}\ldots d_0$ in radix (or base) r, then the value of that numeral is $\sum_{i=0}^{n-1} r^i d_i$, which is just fancy notation to say that instead of a 10's or 100's place we have an r's or $r^2$'s place. For the three radices, binary, decimal, and hex, we just let r be 2, 10, and 16, respectively. We don't have calculators during exams, so let's try this by hand. Recall that our preferred tool for writing large numbers is t he IEC prefixing system:

- $\mathrm{Ki\ (Kibi)} = 2^{10}$
- $\mathrm{Gi\ (Gibi)} = 2^{30}$
- $\mathrm{Pi\ (Pebi)} = 2^{50}$
- $\mathrm{Zi\ (Zebi)} = 2^{70}$
- $\mathrm{Mi\ (Mebi)} = 2^{20}$
- $\mathrm{Ti\ (Tebi)} = 2^{40}$
- $\mathrm{Ei\ (Exbi)} = 2^{60}$
- $\mathrm{Yi\ (Yobi)} = 2^{80}$

   a. Convert the following numbers from their initial radix into the other two common radices: (3 points)

      1. 0b10010011
      2. 63
      3. 0b00100100
      4. 0
      5. 39
      6. 437
      7. 0x0123

   b. Convert the following numbers from hex to binary: (3 points)

      1. 0xD3AD
      2. 0xB33F
      3. 0x7EC4

   c. Write the following numbers using IEC prefixes: (3 points)

      • $2^{16}$
      • $2^{34}$
      • $2^{27}$
      • $2^{61}$
      • $2^{43}$
      • $2^{47}$
      • $2^{36}$
      • $2^{58}$

   d. Write the following numbers as powers of 2: (3 points)

      • 2 Ki
      • 256 Pi
      • 512 Ki
      • 64 Gi
      • 16 Mi
      • 128 Ei

3. If we only have shift registers and adders, how to implement a system
   a. that can multiply any integer by 3? (7 points)
   b. if we change the multiplicand to 7? (7 points)
   c. if the integer will be divided by 3? (7 points)

   *2’s complement can be used to solve the above questions.

4. If we have two real number a=10.6 and b=-31.7,

a. provide the binary representation for int x = a, unsigned ux = b, float y = a, double z = b; (7 points)

b. if float x = a, double y = b, float z = x*y, what's the binary representation for z? (7 points)

c. if float x = a, double y = b, float z = x+y, give the detailed procedures to compute z = x+y (7 points)

5. A system below is designed to do the 32b fixed-point MAC operation. It has an n*n array of the multipliers. The operands $A(a_{32}\ldots a_4a_3a_2a_1a_0)$ and $B(b_{32\ldots}b_5b_4b_3b_2b_1b_0)$ are the two inputs of the multiplier. Output Y has 64 bits. Assuming operand B is a constant and stored in the multiplier. The multiplication is based on the shift and add operation ($\ldots\ a_2*B*2^2+\ a_1*B*2^1+\ a_0*B*2^0$, where $*2^n$ is achieved by the shift operation). We have two assumptions: 1. the data for B follow the gaussian distribution and their means is 0; 2. when a bit in B is 0, there is no power consumption. To minimize the power consumption, what kind of binary representation should we use? Please draw a block diagram of the multiplier and explain why it helps to reduce the power consumption. (12 points)