EE362 Introduction to Computer Architecture

Assignment 1 Solutions

1.1 The PowerPC 601 processor addresses a maximum of 2^{32} bytes of memory. What is the maximum number of 64-bit words that can be stored in this memory?

Solution

There are eight 8-bit words (bytes) in a 64-bit word, which is the same as saying there are 2^3 bytes in a word. Therefore there are

$$\begin{aligned}\frac{2^{32}\text{ bytes}}{2^3\text{ bytes/word}} &= 2^{29}\text{ words}\\ &= 536,870,912\text{ words}\\ &= 536,871\text{ kwords}\\ &= 524,288\text{ Kiwords}\\ &= 537\text{ Mwords}\\ &= 512\text{ Miwords.}\end{aligned}$$

Recognizing the ambiguity inherent in using SI prefixes to refer both to ordinary SI multiples (powers of 10^3) and to binary multiples (powers of 2^{10}), in 1998 the International Electrotechnical Commission (IEC) approved as an IEC International Standard names and symbols for prefixes for binary multiples for use in the fields of data processing and data transmission. These are summarized in Table 1.

Factor	Name	Symbol	Origin		Derivation	
2^{10}	kibi	Ki	kilobinary:	$(2^{10})^1$	kilo:	$(10^3)^1$
2^{20}	mebi	Mi	megabinary:	$(2^{10})^2$	mega:	$(10^3)^2$
2^{30}	gibi	Gi	gigabinary:	$(2^{10})^3$	giga:	$(10^3)^3$
2^{40}	tebi	Ti	terabinary:	$(2^{10})^4$	tera:	$(10^3)^4$
2^{50}	pebi	Pi	petabinary:	$(2^{10})^5$	peta:	$(10^3)^5$
2^{60}	exbi	Ei	exabinary:	$(2^{10})^6$	exa:	$(10^3)^6$

Table 1: Prefixes for Binary Multiples. Taken from Marcel Heldoorn, *The* `SIunits` *package*, `http://www.ctan.org/tex-archive/macros/latex/contrib/SIunits/SIunits.pdf`, printed 1 August, 2002.

1.6

a. What is the percentage relative error in using 2^{10} as an approximation for 10^3?

Solution

$$\epsilon = \frac{2^{10} - 10^3}{10^3} = 2.40\%.$$

b. What is the percentage relative error in using 2^{30} as an approximation for 10^9?

Solution

$$\epsilon = \frac{2^{30} - 10^9}{10^9} = 7.37\%.$$

c. What is the general formula for the relative error in using 2^{10k} as an approximation for 10^{3k}?

Solution

$$\begin{aligned}\epsilon &= \frac{2^{10k} - 10^{3k}}{10^{3k}} \\ &= \left(\frac{2^{10}}{10^3}\right)^k - 1.\end{aligned}$$

1.8 Consider computing the electric field in a box 1.5 cm on a side. The spatial resolution in each dimension is to be 50 μm. Assume that it takes 150 instructions for every point in the 3-D grid to do the calculation. How long does the computation take on a computer that can execute at a rate of 100 MFOPS (millions of floating point instructions per second)?

SOLUTION

First we need to compute the number of points at which the field will be calculated. Let the length of a side be $l = 1.5$ cm, the distance between points on a side be $\Delta = 50$ μm, the number of instructions required per point be $n_p = 150$ instructions/point, and the rate of execution be $r = 100 \times 10^6$ instructions/s. The number of points p_s on each side of length l is

$$\begin{aligned} p_s &= l/\Delta + 1 \\ &= \frac{1.5\text{ cm/side}}{50\ \mu\text{m/gap}} + 1\text{ extra point/side} \\ &= 301\text{ points/side.} \end{aligned}$$

Therefore, the number of points p in the entire box is

$$p = p_s^3 = (301\text{ points})^3 = 27.27 \times 10^6\text{ points.}$$

Now we can calculate the total number n of instructions executed as

$$\begin{aligned} n &= n_p p \\ &= (150\text{ instructions/point})\left(27.27 \times 10^6\text{ points}\right) \\ &= 4.091 \times 10^9\text{ instructions.} \end{aligned}$$

Finally we can compute the time T to complete the computation as

$$\begin{aligned} T &= n/r \\ &= \frac{4.091 \times 10^9\text{ instructions}}{100 \times 10^6\text{ instructions/s}} \\ &= 40.91\text{ s.} \end{aligned}$$