CSSE2010 / CSSE7201 – Introduction to Computer Systems
Answers to Exercises – Week Thirteen
Buses, Pipelines, Floating Point

Answers

1. Calculate how long it would take to transfer 100Mbytes (100 x 10^6 bytes) over
   (a) a 32-bit 33MHz PCI 1 bus
   (b) a 64-bit 66MHz PCI 2.2 bus
   (c) a PCI Express (PCIe, version 1) x1 bus
   (d) USB full-speed bus
   (e) USB hi-speed bus
   Assume that it is possible to sustain the maximum possible transfer rate for the whole transfer. (This is unlikely in practice.)
   The table below summarises the answers. Remember that a transfer rate of 1 Mbyte per second is the same as 8 x 10^6 bits per second (8Mbps). The time taken (in seconds) is the amount of data (in Mbytes) divided by the transfer rate (in Mbytes per second).

Bus Type	Transfer Rate (bits per second)	Transfer Rate (Mbytes per second)	Time taken (at maximum rate).
32-bit 33MHz PCI 1	32 x 33 x 10^6	132	0.758 seconds
64-bit 66MHz PCI 2.2	64 x 66 x 10^6	528	0.189 seconds
PCI Express x 1	2 x 10^9	250	0.4 seconds
USB full-speed	12 x 10^6	1.5	66.67 seconds
USB hi-speed	480 x 10^6	60	1.667 seconds

2. A certain processor has a pipeline composed of four stages, labeled "fetch", "decode", "operand fetch" and "execute". Each of these has a latency (total time) of 1, 1, 2, and 3 clock cycles respectively. (The operand fetch and execute stages are themselves pipelined with substages taking one clock each.)

   Although the question refers to "operand fetch" and "execute" as single stages, because they take more than one clock cycle, they are in effect 2 and 3 substages respectively. We call these O1 and O2, and E1, E2, and E3.

   (a) Draw a diagram of a stream of instructions (ignore branches) flowing through the pipeline, showing individual instructions and how they progress through the pipeline over time.

F	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
D		*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
O1			*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
O2				*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
E1					*1*	*2*	*3*	*4*	*5*	*6*	*7*
E2						*1*	*2*	*3*	*4*	*5*	*6*
E3							*1*	*2*	*3*	*4*	*5*

Time: 1 2 3 4 5 6 7 8 9 10

(b) How long does it take for the first instruction to progress through the pipeline?
Seven cycles.

(c) What is the latency of this pipeline?
Seven clock cycles.

(d) What is the maximum throughput of this pipeline, (i.e. assuming no stalls)?
One instruction per clock cycle

3. What is the decimal value of the IEEE floating point number 0xBF800000?
0xBF800000 is 1011 1111 1000 0000 0000 0000 0000 0000 in binary. This can be regrouped as 1 01111111 00000000000000000000000 (32 bits in total).
The sign bit is 1 so the answer is negative.
The exponent is 01111111, i.e. 127. This is an excess-127 format so the exponent value is 0.
The mantissa is 1.00000… (binary). (The bits after the binary point are the last 23 bits in the 32 bits above.)
The decimal value of the number is therefore $-1.0 \times 2^0 = -1$

4. What are the IEEE single and double precision floating point representations (in hexadecimal) of
(a) –3.25
The number is negative so the sign bit is 1.
The value (3.25) can be written in binary fixed point notation as 11.01 which can be rewritten in normalised form as 1.101×2^1.
For the single precision representation:
  The exponent value (1) when expressed in 8-bit excess-127 format is 10000000 (i.e. 128).
  The 23 mantissa bits are those after the binary point in the normalised form, i.e. 1010000…
  The 32-bit binary representation is therefore 1 10000000 10100000000000000000000
  Grouping these into 4-bit groups: 1100 0000 0101 0000 0000 0000 0000 0000
  Converting each group to a hexadecimal digit gives us: C0500000
For the double precision representation:
  The exponent value (1) when expressed in 11-bit excess-1023 format is 10000000000 (i.e. 1024)
  The 52 mantissa bits are those after the binary point in normalised form, i.e. 1010000…
  The 64-bit binary representation is therefore 1 10000000000 10100000….0000
  Grouping these into 4-bit groups: 1100 0000 0000 1010 0000 0000 …
  Converting each group into a hexadecimal digit gives us: C00A000000000000 (16 hex digits total)

(b) +75.125
The number is positive so the sign bit is 0.
The value (75.125) can be written in binary fixed point notation as 1001011.001 which can be rewritten in normalised form as 1.001011001×2^6.
For the single precision representation:
  The exponent value (6) when expressed in 8-bit excess-127 format is 10000101 (i.e. 133).
  The 23 mantissa bits are those after the binary point in normalised form, i.e. 00101100100…
  The 32-bit binary representation is therefore 0 10000101 00101100100000000000000
  Grouping these into 4-bit groups: 0100 0010 1001 0110 0100 0000 0000 0000
  Converting each group to a hexadecimal digit gives us: 42964000
For the double precision representation:
  The exponent value (6) when expressed in 11-bit excess-1023 format is 10000000101 (i.e. 1029)
  The 52 mantissa bits are those after the binary point in normalised form, i.e. 00101100100…
  The 64-bit binary representation is therefore 0 10000000101 001011001000…000
  Grouping these into 4-bit groups: 0100 0000 0101 0010 1100 1000 0000 …
  Converting each group into a hexadecimal digit gives us: 4052C80000000000 (16 hex digits total)