NATIONAL UNIVERSITY OF SINGAPORE

SEMESTER EXAMINATION FOR THE DEGREE OF B. SC.

SEMESTER 1

CZ1101 - BASIC COMPUTER ARCHITECTURE AND ASSEMBLY PROGRAMMING

November 1997 — Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES

1. This examination paper contains **SIX (6)** questions and comprises **SIX (6)** printed pages (including three pages of Appendices).
2. Answer **ALL** the questions.
3. Candidates may use calculators. However, they should lay out systematically the various steps in the calculations.

1. Describe briefly (in one or two sentences) the following concepts:

(a) stored-program (von Neumann) concept;

(b) virtual memory;

(c) cache;

(d) datapath.

12 marks

2. Follow and comment the code. Specify the value in register or memory when it is affected.

```
      ori  $5, $0, 20
      addi $2, $0, -1
      andi $3, $2, 3
Loop: slt  $4, $2, $3
      beq  $4, $0, Exit
      sw   $3, 0($5)
      addi $3, $3, -2
      addi $5, $5, 4
      j Loop
Exit: lw   $3, -8($5)
```

15 marks

3. Since the MIPS architecture is 32-bit, arithmetic in 64-bit needs to be done with two registers and few more steps. Write a sequence of MIPS assembly instructions to do a 64-bit two's complement addition. Explain clearly how your 64-bit values are represented by the 32-bit registers.

15 marks

4. (a) State the Booth algorithm (as performed by a machine or program).

(b) *Without* actually carrying out the computation, what should be the results (as 8-bit two's complement values) of 4-bit two's complement binary number multiplication for $1111_{two} \times 1110_{two}$ and $1010_{two} \times 0001_{two}$?

(c) Following the steps you have given in (a) for the Booth algorithm, execute step by step $1110_{two} \times 1011_{two}$. What is the equivalent computation in ordinary decimal notation?

18 marks

5. A 32-bit pattern

```
0010 0000 0011 0000 0000 0000 0000 0000
```

can be interpreted in various ways.

(a) What decimal value does it represent if it is interpreted as unsigned 32-bit integer?

(b) What decimal value does it represent if it is interpreted as 32-bit two's complement integer?

(c) What decimal floating-point value does it represent if it is interpreted as an IEEE single-precision floating point number? In the IEEE single-precision floating-point format, the most significant bit (bit 31) is the sign bit, followed by 8 bits for the biased exponent (with bias 127), and the rest of 23 bits for the fraction.

(d) What is the symbolic form of MIPS instruction if it is interpreted as an instruction (c.f. Appendix B)?

(e) What characters do they represent if it is interpreted as four ASCII characters (c.f. Appendix C)?

20 marks

6. Translate the following C segment into MIPS assembly instructions. We assume that the array `a[ ]` starts from memory location 1500, `k` is associated with register \$15, and `c` with \$16. The percent sign `%` in C is the modulo operation (i.e. `(k%3)` is the remainder of k when divided by 3).

```
k = 12;
while( k>=0 ) {
   a[k] = a[k+1] - c;
   if ( (k%3) == 0 ) {
      a[k] = 0;
   }
   --k;
}
```

See Appendix A for a summary of MIPS instructions.

20 marks

— End of the Paper —

CZ1101, Nov 1997, Answers

1: (a) Instructions are represented as numbers; and programs can be stored in memory to be read or written just like numbers. (page 108 of the text book). (b) Use disk as part of the main memory, but transparent to the user (page 481). (c) A small but fast memory taking the advantage of spatial and temporal locality to give user the illusion of fast and large memory (page 458). (d) Part of CPU, the brawn of the computer responsible for arithmetic and logical computation.

2:

```
      ori  $5, $0, 20    # $5=20
      addi $2, $0, -1    # $2=-1
      andi $3, $2, 3     # $3=3
Loop: slt  $4, $2, $3    # $4=1          $4=1        $4=0
      beq  $4, $0, Exit  # no branch     no branch   branch to Exit
      sw   $3, 0($5)     # mem[20]=3     mem[24]=1
      addi $3, $3, -2    # $3=1          $3=-1
      addi $5, $5, 4     # $5=24         $5=28
      j Loop             # jump back     jump back
Exit: lw   $3, -8($5)                                $3=mem[20]=3
```

3:

```
addu $14, $10, $12   # first number is ($11, $10)
sltu $15, $14, $10   # second number   ($13, $12)
addu $15, $15, $11   # result          ($15, $14)
addu $15, $15, $13   # even register for low word
```

4: (a) Let M be n-bit multiplicand, P $2n$-bit product, with intial value $P_h = 0$, $P_l = A$, and a one bit register $C = 0$. P_h is the upper n bits, and P_0 is the least significant bit. The result of $M \times A$ is obtained by following the steps n times: (1) if $(P_0, C) = (1, 1)$, or (0,0), do nothing; if $(P_0, C) = (1, 0)$, do $P_h \leftarrow P_h - M$; if $(P_0, C) = (0, 1)$, do $P_h \leftarrow P_h + M$. (2) Set $C = P_0$; arithmetic shift P to the right 1 bit.

(b) $1111_{two} \times 1110_{two} = (-1)_{ten} \times 1110_{two} = 00000010_{two}$ by the rule of negating. $1010_{two} \times 0001_{two} = 1010_{two} \times 1 = 11111010_{two}$ by sign extension.

(c) In decimal $(-2) \times (-5) = 10 = 0001010_{two}$. In machine way with `M=` 1110_{two}

```
step          P       C
 0         0000 1011   0
 1   -M    0010 1011   0
     >>    0001 0101   1
 2   >>    0000 1010   1
 3   +M    1110 1010   1
     >>    1111 0101   0
 4   -M    0001 0101   0
     >>    0000 1010   1
```

5: (a) 540016640; (b) same as (a); (c) $s = 0$, $e = 2^6 = 64$, $f = 0.011_{two} = 0.375$, value is $1.375 \times 2^{64-127} = 1.49077798 \times 10^{-19}$; (d) `addi $16, $1, 0`; (e) the charater ␣ (space), `0` (zero), `Null`, and `Null`.

6:

```
      addi $15, $0, 12
      addi $3, $0, 3
loop: slt $1, $15, $0
      bne $1, $0, Exit
      mul $17, $15, 4
      lw  $18, 1504($17)  # load a[k+1]
      sub $18, $18, $16   # a[k+1]-c
      sw  $18, 1500($17)  # a[k] = value
      div $15, $3         # k/3
      mfhi $2             # remainder
      bne  $2, $0, L      # if (k mod 3) == 0
      sw   $0, 1500($17)  # then a[k] = 0
   L: addi $15, $15, -1   # --k
      j loop
Exit:
```