EE316 Embedded Systems & Applications

Minor-I

Marks: 20 (Open Book) Time: 2 hrs

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1. A certain CPU has only one *W*-bit internal bus, to which each register (general purpose GPR's, program counter PC, stack pointer SP, etc.) can be connected through controlled *in*- and *out-gates*. Thus R_0 can be loaded from the bus by activating ("strobing") gate R_{0in}, while its contents can be moved to the bus by strobing R_{0out}, and so on.

   The ALU for the CPU takes operand **B** directly from the bus, while operand **A** is input through an A_{in} gate to the ALU register *A* that feeds it directly to the ALU. The content of *A* can be loaded on to the bus through an A_{out} gate bypassing the ALU. The result of an ALU operation can be loaded to an ALU register *Z* by strobing a Z_{in} gate, while the content of *Z* can be loaded to the bus by strobing a Z_{out} gate.

   Assume that the propagation skew through the bus and the ALU are 10ns and 100ns, respectively, while the setup-and-hold time for each register is 8ns. What is the minimum total skew for

   a. Transfer of data residing in one register to another one (neither inclusive of *A* or *Z*) ?
   b. Increment of the PC ? ...(2+4)

2. An A/D converter converts an analog input voltage to a twelve-bit output word. This word is accepted by an Intel 8086 processor, that converts the A/D output to a 16b exponential format with a normalised signed/two's-complement mantissa over 11b, and an *excess-16* 5b exponent. Corresponding to the maximum and minimum (non-zero) A/D output, what will be the 16b exponential format data words for the computer ?
   ...(1+3)

3. An Intel 8088 based computer has a *large model* code residing from location addresses 256AEH to 52E89H contiguously, and does not involve linking to functions and libraries residing elsewhere in the memory. The code includes an inner loop between 36750H to 48AC3H that is executed hundred times, and an outer loop between 3188FH and 52506H that is executed fifty times as part of the overall code execution. How many times during the entire execution does the CS register need to be changed within the assembly code, assuming no segment overrides for the CS?
   ...(5)

4. A computer is to be setup to receive characters from twenty video terminals. All terminals use the same interrupt vector INTVEC in the main memory, and in all cases the input date is to be collected while another front end program PROG is undergoing execution. This may be achieved in either of two ways.
   a. Every *T* seconds, the PROG calls a subroutine DEVSUB. Once called, this routine checks all twenty terminals in sequence, and transfers characters from whichever is ready with one. It then returns to PROG.
   b. While PROG is in execution, a terminals that is ready with a character send an interrupt that is serviced by an ISR DEVINT. After polling the status registers, DEVINT transfers the input character and then returns to PROG.

   Each terminal can send a maximum of *c* mega-characters per second, with an average sending rate of *rc* per second (*r* less than unity). Each bus transfer requires 0.3μs. In method "a", what value of *T* ensures that no character is lost ? What is the equivalent condition for method "b" ?
   ...(5)

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Solutions to Minor-I

1.

a. One bus propagation skew + one register setup+hold = 10 + 8 = 18ns.

b.

PC-to-bus	=	10ns
Bus-to-*A*	=	8ns
#1-to-bus	=	10ns
ALU (Add)	=	100ns
Load-*Z*	=	8ns
Z-to-bus	=	10ns
Bus-to-PC	=	8ns
TOTAL SKEW	=	154ns

(2+4 marks)

2. The maximum number to be stored is the decimal unity, which corresponds to A/D word FFF. Thus the maximum data word will be **0010h**, equivalent to 1 (leading default) x 2^0, where the index zero is equivalent to 10h in *excess-16* format.

The minimum non-zero A/D output is 001, which is $1/2^{12}$ = 1 (leading default) x 2^{-12}. The minimum data word will therefore be **0004h**, as 04h is equivalent to –12 in *excess-16*.

(1+3 marks)

3. For each outer loop, the inner loop requires the CS to change from 3675H to 48ACH = that is, by 1237H + 1 = 4664 values, a hundred times. This implies a total of 466 400 changes of CS *for every outer loop*, which makes it a total of 466 400 x 50 = 2332 0000 times.

The outer loop changes the CS fifty times in two stretches:

- From 3188H to 3675H "above the inner loop" = 04EDH = 1261 values
- From 48ACH to 5250H "below the inner loop" + 1 = 09A4H + 1 = 2469 values

The total number of changes in the CS due to the outer loop is (1261 + 2469) * 50 = 18 6500 times.

"Above the outer loop", the CS changes from 256AH to 3188H = 0C1EH = 3102 times.
"Below the outer loop", the CS changes from 5250H to 52E8H = 0098H = 152 times.

The total number of CS changes for the entire long model program is 23509754 which is approximately 23.51mega changes.

(5 marks)

4. Assuming that each terminal send characters continuously, the time to send each character is $1/c$ μs.
Since each bus transfer requires 0.3μs, each terminal requires $(1/c + 0.3)$μs for each character.

So to handle the worst case of option "a", the minimum value of T in option "a" must be $20.(1/c+0.3)$μs. To send rc characters, we need $20r(1+0.3c)$μs.

In option "b", a terminal still requires the same time for each character. However to send rc characters, the system as a whole requires $r(1+0.3c)$μs, since only handshaking is involved.

(5 marks)