Version AHG/2

EGT2
ENGINEERING TRIPOS PART IIA

Wednesday 29 April 2015 9.30 to 11

Module 3F5

COMPUTER AND NETWORK SYSTEMS

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

*Write your candidate number **not** your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Engineering Data Book

10 minutes reading time is allowed for this paper.

You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

1 (a) Explain what is meant by a *pipelined* datapath. What are pipeline *hazards*? [20%]

(b) A data forwarding unit is to be added to the MIPS datapath in Fig. 1. Sketch the relevant part of the enhanced datapath, showing how the forwarding unit is connected to the other components. [20%]

(c) The following extract of MIPS code increments all the elements of an n-element array by the contents of `$10`. Each element of the array is four bytes. The starting address of the array is `Astart` and $4n$ is in `$11`.

```
       add $9,$0,$0       # clear $9 to zero
Loop:  lw $8,Astart($9)   # $8 loaded with data at address $9+Astart
       add $8,$8,$10      # $8 loaded with $8+$10
       sw $8,Astart($9)   # $8 stored at address $9+Astart
       addi $9,$9,4       # $9 loaded with $9+4
       bne $9,$11,Loop    # Jump back 4 instructions if $9≠$11
```

The code is run on the enhanced datapath in (b). Any remaining data hazards are resolved by stalling. Branches are assumed to be not taken, with pipeline flushing if they are taken. Calculate the minimum number of clock cycles required to execute the code:

(i) as is; [10%]

(ii) after re-ordering the instructions and adjusting offsets as necessary; [15%]

(iii) after unrolling the loop by a factor of two (i.e. looping $n/2$ times and incrementing two array elements each time around the loop). Assume n is even. [15%]

(d) Now consider a *delayed branch* model, with one delay slot and no flushing or stalling whether the branch is taken or not. Comment on the necessary hardware modifications and how the code in (c) might be tweaked to exploit the delayed branch. [20%]

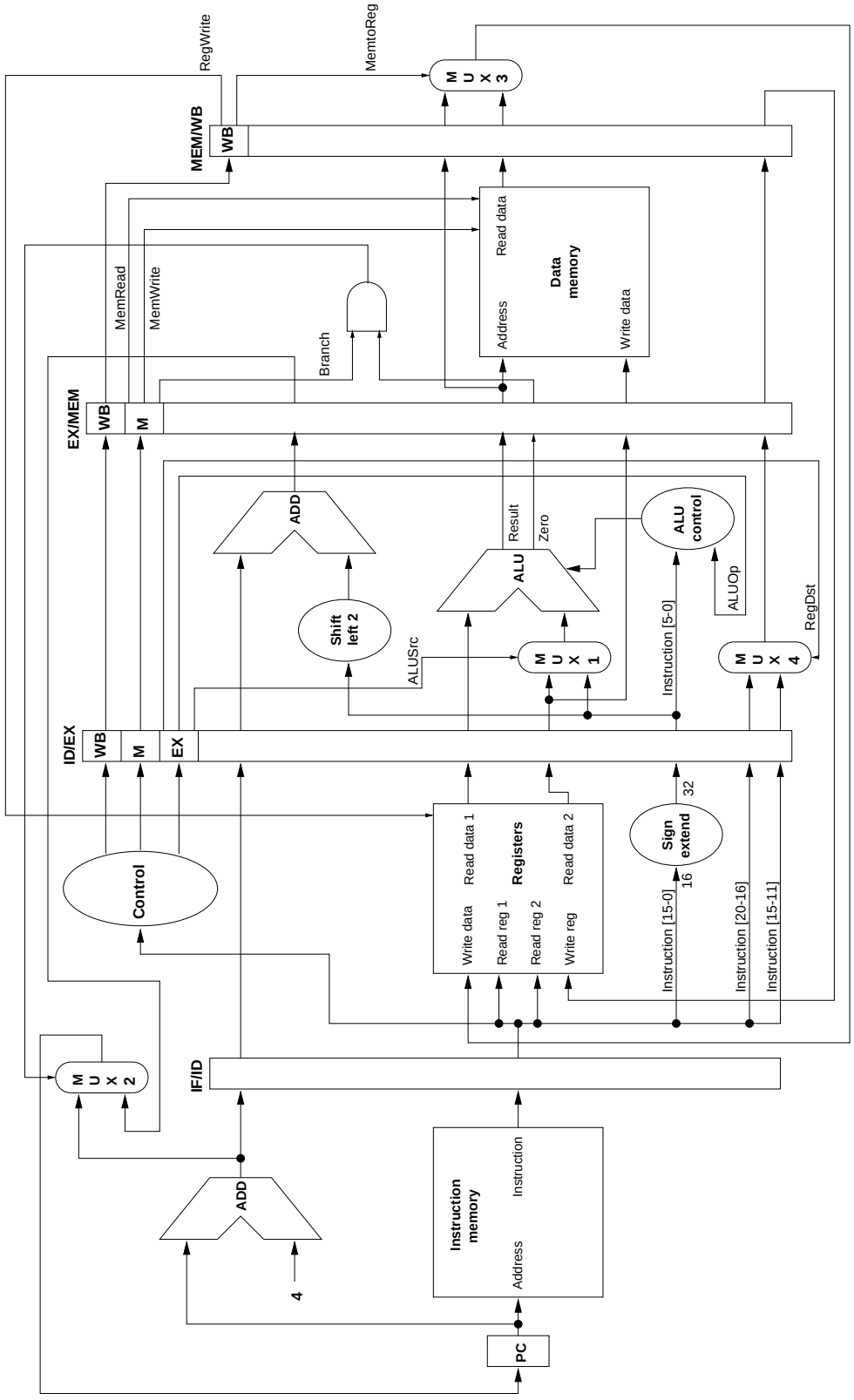
RegWrite
MemtoReg
M U X 3
MEM/WB
WB
Read data
Data memory
Address
Write data
MemRead
MemWrite
Branch
EX/MEM
WB
M
ADD
Result
Zero
ALU control
ALU
ALUOp
Shift left 2
ALUSrc
M U X 1
Instruction [5-0]
M U X 4
RegDst
ID/EX
WB
M
EX
32
Sign extend
16
Control
Read data 1
Registers
Read data 2
Write data
Read reg 1
Read reg 2
Write reg
Instruction [15-0]
Instruction [20-16]
Instruction [15-11]
M U X 2
IF/ID
ADD
4
Instruction memory
Instruction
Address
PC

Fig. 1

2 (a) Discuss the relative advantages and disadvantages of polling, interrupt-driven I/O and direct memory access (DMA). For each method, suggest one common I/O task for which it might be used. [25%]

(b) What precautions must be taken when using DMA in conjunction with caches and virtual memory systems? [25%]

(c) Traditionally, a chipset would contain a single DMA controller. More recently, DMA controllers have been built into the I/O devices themselves, with one per device. Discuss the possible reasons behind this evolution, paying particular attention to modern I/O standards like serial ATA (SATA) and PCI express (PCIe). [25%]

(d) A gigabit network interface controller (NIC) uses DMA to copy incoming data packets into main memory. A DMA transfer may involve (i) copying a single packet and then interrupting the CPU to indicate that the packet is available, or (ii) *interrupt coalescing*, whereby multiple packets are copied before the interrupt, with an upper limit T on the time between the arrival of a packet at the NIC and the post-DMA CPU interrupt. Discuss the relative advantages and disadvantages of the two schemes. [25%]

3 (a) Explain with the aid of a simple sketch how a Connection Oriented Transport Service (COTS) works. What are the key features of a COTS service? Illustrate your answer with an example of a typical network which uses the COTS principles. [25%]

(b) What are the advantages and disadvantages of a network service based on the COTS principles? Use the example of the Ethernet protocol to demonstrate how these principles have evolved over the past twenty years. [25%]

(c) The types of services used by the application layer have a strong influence on the effective function of a network. Explain why one service in particular has led to the redeployment of many of the COTS principles by network providers. [25%]

(d) Describe two examples of recently developed protocols which have adopted the COTS principles. [25%]

4 (a) One of the hot topics in the communications world is the "Internet of Things" (IoT), where many different devices and technologies are internet-enabled. If we assume that Internet Protocol version 4 (IPv4) is in use, then given no address classes, how many "things" could be connected to the internet? Hence explain why IPv4 is a severe limitation on the IoT. What sort of technique could be used to alleviate this problem without having to change from IPv4? [30%]

(b) Another problem with the IoT will be the volume of IPv4 traffic that must be routed across the internet. One of the key concepts of internet routing is the *fast path*. Use a simple diagram to explain what the fast path does and discuss whether this is an advantage or not when used with the IoT. [30%]

(c) A lot of the devices that will form the IoT will have to be wireless-enabled in order to allow them to be mobile. What sort of network might be best suited for this kind of wireless application? Use examples of two different wireless network protocols to illustrate your answer and discuss their relative advantages and disadvantages. [30%]

(d) Given the current expansion of internet users and applications, comment on what might be the eventual limitation on the IoT. [10%]

END OF PAPER

Part IIA 2015

Module 3F5: Computer and Network Systems

Numerical Answers

1. (c) (i) $9n + 2$ (ii) $8n + 2$ (iii) $11n/2 + 2$

4. (a) 4.3×10^9 things