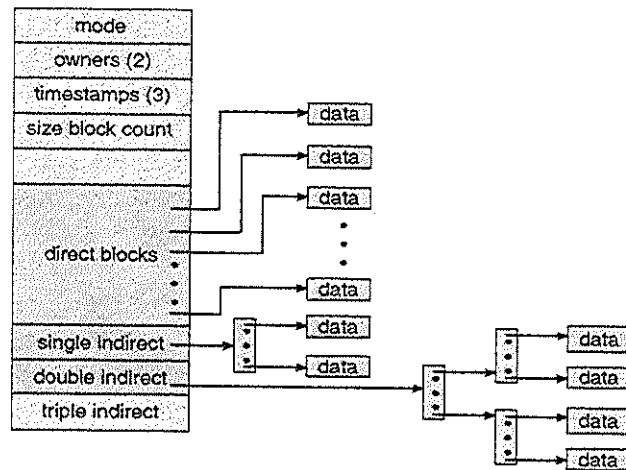


- 1.
- (a) (8 pt) Suppose N processes with IDs $0, 1, 2, \dots, N - 1$ need to share some critical region of code, which only one at a time is allowed to execute, and where they are required to repeatedly cycle through this section in the natural order $(0, 1, 2, \dots, N - 1)$. If `turn` is a shared integer variable initialized to zero, and `current_pid` is the ID of the currently executing process, and each executes the following pseudo-code, could a race condition occur? Why or why not? Be precise.

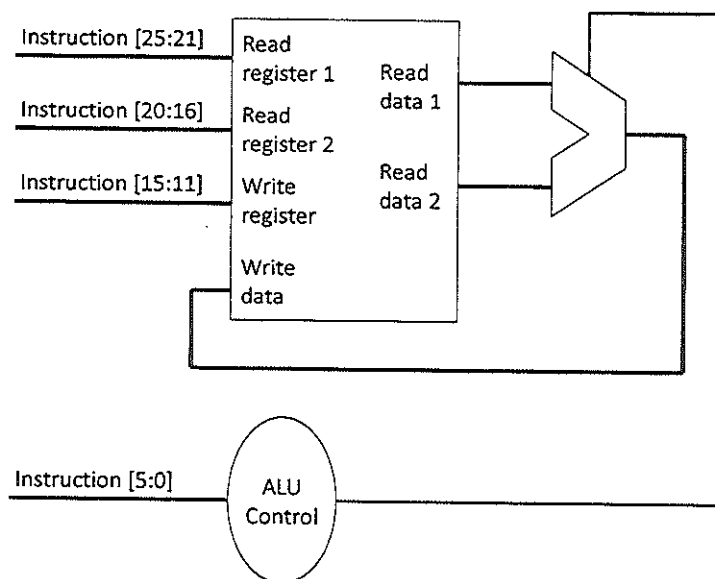
```
while(TRUE)
{
    while(turn != current_pid); /* wait */
    critical_region();
    turn = (turn + 1) % N;
    noncritical_region();
}
```

- (b) (8 pt) How many semaphores would be required if a semaphore solution to this problem was used instead? Write some pseudo-code for this.
2. Three processes A, B and C start executing (nearly) together in a multiprocessing environment, and require 7, 12 and 16 seconds, respectively, of run time. What will the average turnaround time be for each of the following scheduling algorithms:
- (a) (2 pt) Shortest Job First scheduling
- (b) (3 pt) Preemptive Round Robin scheduling
- (c) (4 pt) Consider a preemptive priority-based scheduling in which a process with priority i will be demoted to priority $i+1$ if it cannot be finished in given time quantum. The time quantum of priority i is 2^i seconds. Assume A, B and C start executing in that order, and each initially starts with priority 0.
3. (10 pt) Consider a file system that use inodes to represent files. Disk blocks are 16KB in size, and a pointer to a disk block requires 2 bytes. The file system keeps 15 pointers of the index block in the file's inode. The first 12 pointers point to direct blocks. The next 3 pointers point to single, double and triple indirect blocks, respectively. What is the maximum size of a file that can be stored in this file system?

Hint:



4. (15 pt) How many page faults occur for the three algorithms named FIFO, Optimal and LRU for the following reference string, for 5 page frames?
1, 2, 3, 4, 1, 3, 9, 4, 5, 6, 9, 7, 8, 9, 7, 9, 4, 3, 2, 5, 1, 6, 7, 8
5. (10 pt) If a 16-bit adder with a carry-in pin is designed by logic gates, and the delay time for an N inputs logic gate is $N \times T$. Please determine and explain if the maximum delay time of this adder can be smaller than $22 \times T$?
6. (15 pt) The following techniques have been developed to reduce cache miss penalty or miss rate: "multi-banked caches", "small and simple caches", and "hardware prefetching of instructions". Please briefly explain these techniques and how they work.
7. The following figure shows the datapath for MIPS R-type ALU instructions.
 - (a) (9 pt) Please list the three additional multiplexors needed to support LW (load word; I-type).



- (b) (6 pt) The program execution time of the single-cycle datapath can be expressed as

$$\text{IC (instruction count)} \times \text{CPI (cycles per instruction)} \times \text{clock cycle time.}$$

Please describe how these three parameters are affected for the multi-cycle implementation & the pipelined implementation respectively.

8. Consider the following MIPS assembly code

```

LOOP:  lw $t0, -4($s0)  # assume $s0 has an initial value of 100
       sw $t0, 996($s0)
       addi $s0, $s0, -4
       bne $s0, $zero, LOOP

```

Exit:

How many cycles does it need for the above loop (i.e. till the last bne taking effect)?

- (3 pt) on a single-cycle datapath;
- (4 pt) on a classical 5-stage pipelined datapath (IF/ID/EX/MEM/WB) with interlock only (no forwarding or branch prediction); Assume bne is resolved at the EX stage.
- (3 pt) on a classical 5-stage pipelined datapath with full forwarding.