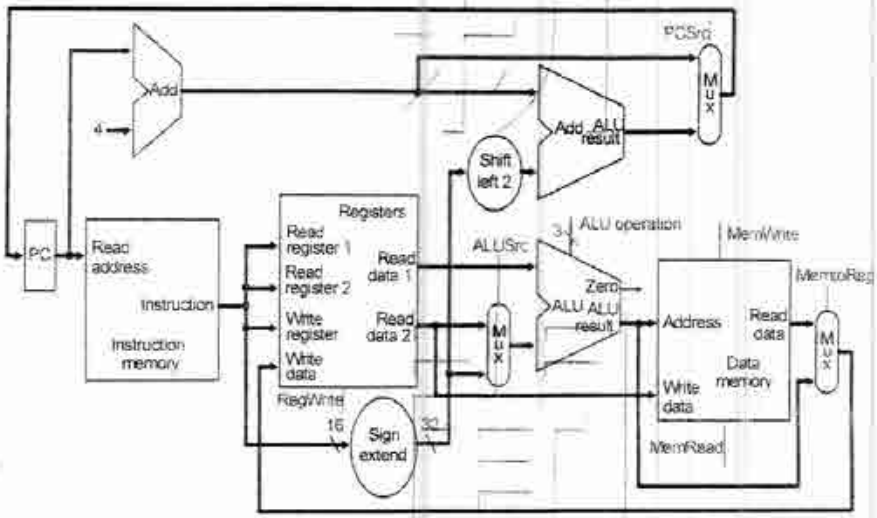
1. **(30 points)** The single-cycle datapath for the MIPS architecture is shown below.



(a) **(4 points)** The single-cycle datapath is not used in modern designs. Why? Please explain in detail.

(b) **(13 points)** What is a multicycle datapath design? Modify the above single cycle datapath as a multicycle datapath. Draw the modified datapath and explain your modification.

(c) **(13 points)** What is a pipelining implementation? Modify the above single cycle datapath as a pipelined datapath. Draw the modified datapath and explain your modification.

2. **(10 points)** Please explain the designs and advantages for RAID 0, 1, 2, 3, and 4, respectively.

3. **(10 points)** An eight-block cache can be configured as direct mapped, two-way set associative, four-way set associative, and fully associative. Draw these cache configurations. Explain the relationship between cache miss rate and associativity.

4. **(10 points)**

(a)(5 points) What property of programs makes cache useful?

(b)(5 points) Does context-switch affect the performance of cache? Explain your answer.

5. **(10 points)**

(a)(5 points) Must the semaphore mechanism be implemented in kernel? Why or Why not?

(b)(5 points) Can busy-waiting be eliminated in such implementation?

6. **(20 points)**

(a)(5 points) Assume that virtual address is 16-bits wide and physical address is 20-bits wide. The page size is 4K bytes. If the mapping is done by paging, how many entries are there in the page table and how many bits does each entry occupy?

(b)(5 points) Explain the demand paging mechanism. Since OS is passive, your answer must also point out how OS knows the demand of a program.

(c)(10 points) The memory access time is 10 ns. But if page fault occurs, the time becomes 10 ms. If we want the effective access time not over 11 ns, what is the maximum page fault rate?
(1 ms=10^{-3} seconds, 1 ns=10^{-9} seconds)

7. **(10 points)** In UNIX, we can link a file named "A" to "B". So whenever we access A, we are actually accessing B. And the link also can be implemented as hard link or soft link. Explain the implementations for such two modes of links.