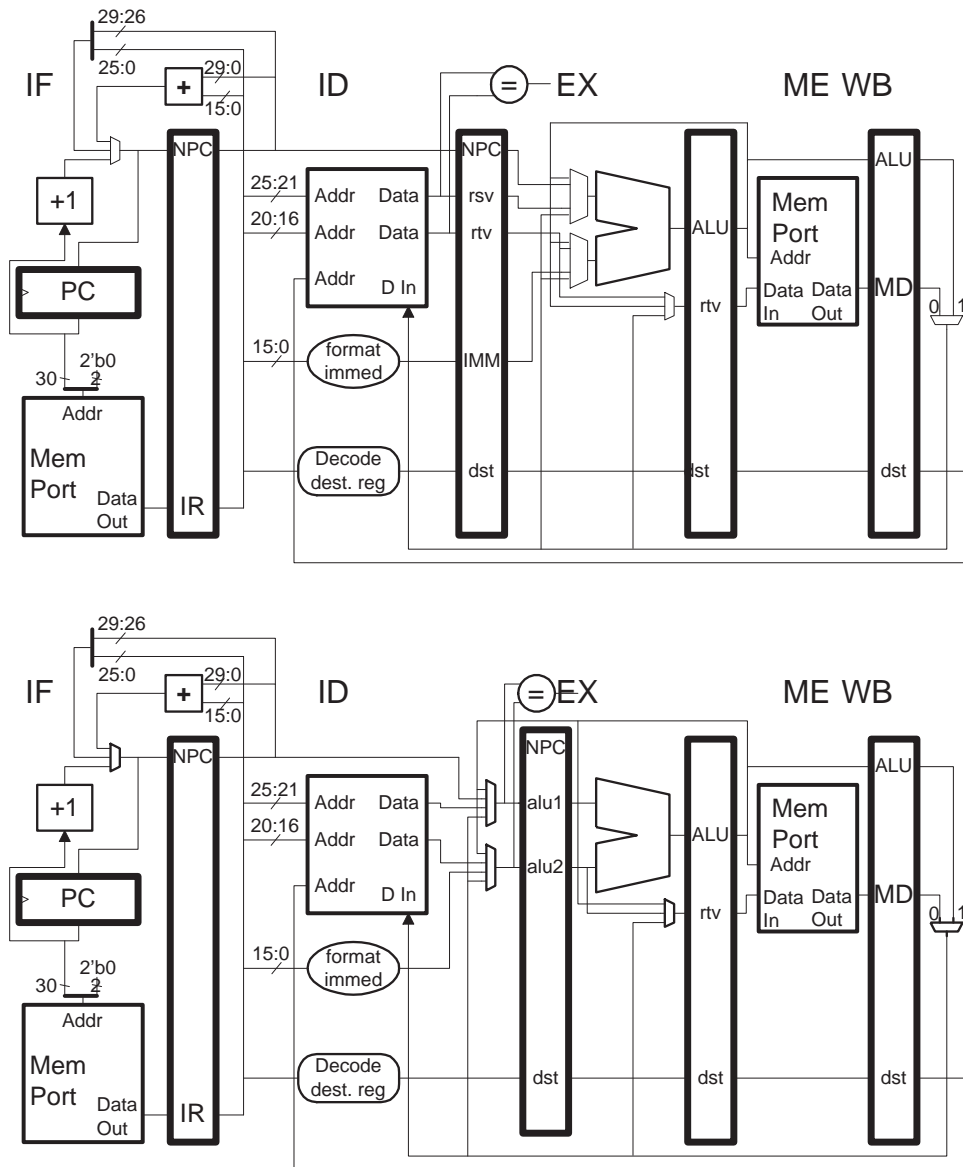


Problem 1: Two MIPS implementations appear below, the first is the one presented in class, it will be called the *mux-in-EX implementation*. The second, the *mux-in-ID implementation*, has the ALU input multiplexers in the ID stage, to better balance critical paths. The clock frequency of the mux-in-EX implementation is 1 GHz and the clock frequency of the mux-in-ID implementation is 1.1 GHz.



(a) With this change some of the ALU multiplexer inputs are unnecessary. Show which inputs are unnecessary and explain why.

Problem continued on next page.

(b) The code below computes the sum of the low 12 bits of elements in an integer array. Compute the performance, in array elements per second, of this code for both the mux-in-EX system and the mux-in-ID system. Assume that the array size is large and that the number of array elements is even.

```
# Call Values
#     $a0,  address of start of array of four-byte integers.
#     $a1,  number of elements in array. Assume > 0 and multiple of 2.
# Return Value
#     $v0,  sum of low 12 bits of integers in array.

        sll $t1, $a1, 2
        add $t1, $a0, $t1
        addi $t1, $t1, -4

LOOP:
        lw $t0, 0($a0)
        lw $t5, 4($a0)
        andi $t2, $t0, 0xfff
        add $v0, $v0, $t2
        andi $t7, $t5, 0xfff
        add $v0, $v0, $t7
        bne $a0, $t1 LOOP
        addi $a0, $a0, 8

        jr $ra
        nop
```

(c) If, after double-checking your work, the performance of the mux-in-ID system is faster than the old mux-in-EX system inform the professor that there is a mistake in this problem. Otherwise, schedule (re-arrange instructions) the code above so that it performs faster (while still performing the same computation) on the mux-in-ID system.

Problem 2: You are in an alternate universe where you work for MIPS at a time when its first implementation (mux-in-EX) has been very successful and is in the hands of customers of all types. You are deciding on whether to make mux-in-ID the second implementation to be marketed.

(a) What role do compiler writers have in the success of mux-in-ID? Explain.

(b) If mux-in-ID is faster than mux-in-EX using the old compilers, do compilers still need to be re-written? Explain.