

Question 3 (10 points):

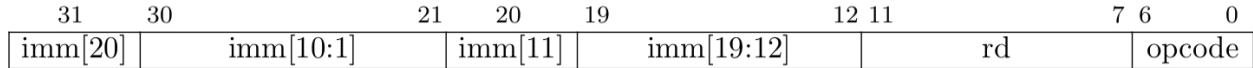


Figure 1: UJ-Type format. Used for jump-and-link instructions in RISC-V.

- a. (5 points) Figure 1 shows the format of an UJ-Type instruction, which is used for a jump-and-link instruction. When a `jal` instruction is executed the value of the new program counter is given by the following expression $PC = PC + \{imm, 1b'0\}$ where $\{imm, 1b'0\}$ is the immediate value in the instruction with an implicit bit 0 equal 0. Assume that a program has a `jal` instruction at address `0x00400040` and that the binary representation of this instruction is `0x0E00006F`. What is the value of the PC after the execution of this instruction expressed in hexadecimal representation?

```

0x0E00006F
0000 1110 0000 0000 0000 0000 0110 1111
i[20] i[10:1]   i[11] i[19:12] rd   opcode
0      0001110000 0      00000000 00000 11011111
imm = 0000000000000011100000
imm = 0000 0000 0000 0000 0000 0000 1110 0000
imm = 0x000000E0
NewPC = 0x00400040+0x000000E0 = 0x00400120

```

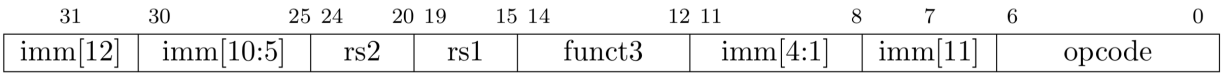


Figure 2: SB-Type format. Used for branch instructions in RISC-V.

Address	Code	Basic	Source
0x004000e8	0x00100293	addi x5,x0,0x00000001	198: li t0, 1
0x004000ec	0x00a00313	addi x6,x0,0x0000000a	199: li t1, 10
0x004000f0	0x0180006f	jal x0,0x0000000c	200: j allocate_mem
0x004000f4	0x03c55eb3	divu x29,x10,x28	202: divu t4, a0, t3
0x004000f8	0x01d00533	add x10,x0,x29	203: mv a0, t4
0x004000fc	0x00128293	addi x5,x5,0x00000001	204: addi t0, t0, 1
0x00400100	0x03c30333	mul x6,x6,x28	205: mul t1, t1, t3
0x00400104	Information omitted for question		206: blt zero, a0, compute_dm
0x00400108	0x00228513	addi x10,x5,0x00000002	208: addi a0, t0, 2

Figure 3: A fragment of code extracted from RARS.

- b. (5 points) Figure 2 shows the SB-Type format used for branch instructions. Figure 3 shows a code fragment, as displayed in RARS, where the binary code and the value of the immediate value in the `blt` instruction have been covered up. The target of the `blt` instruction is the instruction at line 202 of the source code. The `funct3` code for a `blt` instruction is 100 and the opcode is 1100011. Knowing that register `zero` corresponds to register `x0`, and that register `a0` corresponds to register `x10`, what is the hexadecimal representation of the binary code for that `blt` instruction?

```

PCtarget-PCblt = 0x004000F4-0x00400104
0x004000F4
0x00400104
-----
0xFFFFFFFF

i[12] i[10:5] rs2  rs1  f3  i[4:1] i[11] opcode
1      111111 01010 00000 100 1000  1      1100011

1111 1110 1010 0000 0100 1000 1110 0011
 f    e    a    0    4    8    e    3

Binary Code:  0xfea048e3

```