Computer Architectures
Exam of 16.09.2024 - part I

First name, Last name, ID.....

Question #2

Let's consider a generic processor that executes 32-bit instructions, uses 32-bit addresses, and performs branch predictions via a Branch Target Buffer (BTB) composed of 4 entries.
Assuming that the BTB only stores branch taken predictions and is initially empty (i.e., full of 0s), report the content of the BTB after the execution of each of the following instructions:

1	dmul r4, r5, r6	located at the address *0x00000048*
2	bne r4, r1, lab1	located at the address *0x0000004c*; the branch is not taken
3	daddui r7, r7, 1	located at the address *0x00000050*
4	j chk **(*)**	located at the address *0x00000054*; the branch is taken, and the branch target address is *0x00000068*
5	daddi r5, r5, -1	located at the address *0x00000068*
6	bnez r4, term	located at the address *0x0000006c*; the branch is taken, and the branch target address is *0x00000048*
7	dmul r4, r5, r6	located at the address *0x00000048*
8	bne r4, r1, lab1	located at the address *0x0000004c*; the branch is taken, and the branch target address is *0x00000058*
9	bne r4, r2, lab2	located at the address *0x00000058*; the branch is not taken
10	daddui r8, r7, 1	located at the address *0x0000005c*
11	j chk **(*)**	located at the address *0x00000060*; the branch is taken, and the branch target address is *0x00000068*
12	daddi r5, r5, -1	located at the address *0x00000068*
13	bnez r4, term	located at the address *0x0000006c*; the branch is taken, and the branch target address is *0x00000048*
14	dmul r4, r5, r6	located at the address *0x00000048*
15	bne r4, r1, lab1	located at the address *0x0000004c*; the branch is taken, and the branch target address is *0x00000058*
16	bne r4, r2, lab2	located at the address *0x00000058*; the branch is taken, and the branch target address is *0x00000064*
17	daddui r9, r8, 1	located at the address *0x00000064*
18	daddi r5, r5, -1	located at the address *0x00000068*
19	bnez r4, term	located at the address *0x0000006c*; the branch is not taken
20	halt	located at the address *0x00000070*

The use of the calculator is forbidden. Before starting to fill the BTB itself, it is necessary to fill in the contents of this table so as to understand which entry of the BTB each instruction will refer to.
Hint: To calculate the BTB entry corresponding to each branch instruction, remember that you should exclude the last two bits from the instruction address as they are always equal to 0.

Instruction	Address in Hex	Address in Binary	Entry No.
dmul r4, r5, r6	0x00000048	0000 0000 0000 0000 0000 0000 0100 **10**00	2
bne r4, r1, lab1	0x0000004c	0000 0000 0000 0000 0000 0000 0100 **11**00	3
daddui r7, r7, 1	0x00000050	0000 0000 0000 0000 0000 0000 0101 **00**00	0
j chk (*)	0x00000054	0000 0000 0000 0000 0000 0000 0101 **01**00	1
daddi r5, r5, -1	0x00000068	0000 0000 0000 0000 0000 0000 0110 **10**00	2
bnez r4, term	0x0000006c	0000 0000 0000 0000 0000 0000 0110 **11**00	3
bne r4, r2, lab2	0x00000058	0000 0000 0000 0000 0000 0000 0101 **10**00	2
daddui r8, r7, 1	0x0000005c	0000 0000 0000 0000 0000 0000 0101 **11**00	3
j chk (*)	0x00000060	0000 0000 0000 0000 0000 0000 0110 **00**00	0
daddui r9, r8, 1	0x00000064	0000 0000 0000 0000 0000 0000 0110 **01**00	1
halt	0x00000070	0000 0000 0000 0000 0000 0000 0111 **00**00	0

Then, describe the state of the BTB in each step and, upon completion, report the total number of correct and incorrect predictions.

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Before starting, it is essential to note the presence of two instructions that look identical but are not: Although they share the same syntax, they occupy different addresses; they are, therefore, to be considered, for all intents and purposes, as different instructions. These instructions are marked with an asterisk in two round brackets **(*)** for easy identification.

0. BTB initial content

Entry No.	Address	Target
0	0x00000000	0x00000000
1	0x00000000	0x00000000

Entry No.	Address	Target
2	0x00000000	0x00000000
3	0x00000000	0x00000000

1. BTB content after ***dmul r4, r5, r6*** execution

Entry No.	Address	Target
0	0x00000000	0x00000000
1	0x00000000	0x00000000

Entry No.	Address	Target
2	0x00000000	0x00000000
3	0x00000000	0x00000000

2. BTB content after ***bne r4, r1, lab1*** execution

Entry No.	Address	Target
0	0x00000000	0x00000000
1	0x00000000	0x00000000

Entry No.	Address	Target
2	0x00000000	0x00000000
3	**0x00000000**	**0x00000000**

3. BTB content after ***daddui r7, r7, 1*** execution

Entry No.	Address	Target
0	0x00000000	0x00000000
1	0x00000000	0x00000000

Entry No.	Address	Target
2	0x00000000	0x00000000
3	0x00000000	0x00000000

4. BTB content after ***j chk (*)*** execution (address 0x00000054)

Entry No.	Address	Target
0	0x00000000	0x00000000
1	**0x00000054**	**0x00000068**

Entry No.	Address	Target
2	0x00000000	0x00000000
3	0x00000000	0x00000000

5. BTB content after ***daddi r5, r5, -1*** execution

Entry No.	Address	Target
0	0x00000000	0x00000000
1	0x00000054	0x00000068

Entry No.	Address	Target
2	0x00000000	0x00000000
3	0x00000000	0x00000000

6. BTB content after ***bnez r4, term*** execution

Entry No.	Address	Target
0	0x00000000	0x00000000
1	0x00000054	0x00000068

Entry No.	Address	Target
2	0x00000000	0x00000000
3	**0x0000006c**	**0x00000048**

7. BTB content after ***dmul r4, r5, r6*** execution

Entry No.	Address	Target
0	0x00000000	0x00000000
1	0x00000054	0x00000068

Entry No.	Address	Target
2	0x00000000	0x00000000
3	0x0000006c	0x00000048

8. BTB content after ***bne r4, r1, lab1*** execution

Entry No.	Address	Target
0	0x00000000	0x00000000
1	0x00000054	0x00000068

Entry No.	Address	Target
2	0x00000000	0x00000000
3	**0x0000004c**	**0x00000058**

9. BTB content after ***bne r4, r2, lab2*** execution

Entry No.	Address	Target
0	0x00000000	0x00000000
1	0x00000054	0x00000068

Entry No.	Address	Target
2	**0x00000000**	**0x00000000**
3	0x0000004c	0x00000058

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10. BTB content after ***daddui r8, r7, 1*** execution

Entry No.	Address	Target
0	0x00000000	0x00000000
1	0x00000054	0x00000068

Entry No.	Address	Target
2	0x00000000	0x00000000
3	0x0000004c	0x00000058

11. BTB content after ***j chk (*)*** execution (address 0x00000060)

Entry No.	Address	Target
0	**0x00000060**	**0x00000068**
1	0x00000054	0x00000068

Entry No.	Address	Target
2	0x00000000	0x00000000
3	0x0000004c	0x00000058

12. BTB content after ***daddi r5, r5, -1*** execution

Entry No.	Address	Target
0	0x00000060	0x00000068
1	0x00000054	0x00000068

Entry No.	Address	Target
2	0x00000000	0x00000000
3	0x0000004c	0x00000058

13. BTB content after ***bnez r4, term*** execution

Entry No.	Address	Target
0	0x00000060	0x00000068
1	0x00000054	0x00000068

Entry No.	Address	Target
2	0x00000000	0x00000000
3	**0x0000006c**	**0x00000048**

14. BTB content after ***dmul r4, r5, r6*** execution

Entry No.	Address	Target
0	0x00000060	0x00000068
1	0x00000054	0x00000068

Entry No.	Address	Target
2	0x00000000	0x00000000
3	0x0000006c	0x00000048

15. BTB content after ***bne r4, r1, lab1*** execution

Entry No.	Address	Target
0	0x00000060	0x00000068
1	0x00000054	0x00000068

Entry No.	Address	Target
2	0x00000000	0x00000000
3	**0x0000004c**	**0x00000058**

16. BTB content after ***bne r4, r2, lab2*** execution

Entry No.	Address	Target
0	0x00000060	0x00000068
1	0x00000054	0x00000068

Entry No.	Address	Target
2	**0x00000058**	**0x00000064**
3	0x0000004c	0x00000058

17. BTB content after ***daddui r9, r8, 1*** execution

Entry No.	Address	Target
0	0x00000060	0x00000068
1	0x00000054	0x00000068

Entry No.	Address	Target
2	0x00000058	0x00000064
3	0x0000004c	0x00000058

18. BTB content after ***daddi r5, r5, -1*** execution

Entry No.	Address	Target
0	0x00000060	0x00000068
1	0x00000054	0x00000068

Entry No.	Address	Target
2	0x00000058	0x00000064
3	0x0000004c	0x00000058

19. BTB content after ***bnez r4, term*** execution

Entry No.	Address	Target
0	0x00000060	0x00000068
1	0x00000054	0x00000068

Entry No.	Address	Target
2	0x00000058	0x00000064
3	**0x00000000**	**0x00000000**

20. BTB content after ***halt*** execution

Entry No.	Address	Target
0	0x00000060	0x00000068
1	0x00000054	0x00000068

Entry No.	Address	Target
2	0x00000058	0x00000064
3	0x00000000	0x00000000

Total number of correct predictions: __**2**__ Total number of incorrect predictions: __**8**__