|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | R | LW | SW | ADDI | ANDI | ORI | XORI | SLTI | BEQ | J | JAL | JR | JALR |
| Op5 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Op4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Op3 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Op2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| Op1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| Op0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Funct5 | D | X | X | X | X | X | X | X | X | X | X | 0 | 0 |
| Funct4 | D | X | X | X | X | X | X | X | X | X | X | 0 | 0 |
| Funct3 | D | X | X | X | X | X | X | X | X | X | X | 1 | 1 |
| Funct2 | D | X | X | X | X | X | X | X | X | X | X | 0 | 0 |
| Funct1 | D | X | X | X | X | X | X | X | X | X | X | 0 | 0 |
| Funct0 | D | X | X | X | X | X | X | X | X | X | X | 0 | 1 |
| Output | | | | | | | | | | | | | |
| ALUOp1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| ALUOp0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| RegDst | 1 | 0 | X | 0 | 0 | 0 | 0 | 0 | X | 0 | 0 | 0 | 0 |
| ALUSrc | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | X | X | 0 | 0 |
| MemtoReg | 0 | 1 | X | 0 | 0 | 0 | 0 | 0 | X | 0 | 0 | 0 | 0 |
| RegWrite | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| MemRead | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MemWrite | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Branch | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Jump | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| RegDst\_ra | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| JumptoReg | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

Main control

D = depends on the operation

X = don’t care

在JR跟JALR先不考慮的情況(那兩個另外處理RegDst, RegDst\_ra, JumptoReg )

(以下數字都是Opcode的值)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | ALUOp1 | ALUOp0 | RegDst | ALUSrc |
| 0 | 2,3,4,8,10,12,13, 14,35,43 | 0,2,3,8,10,12,13, 14,35,43 | 2,3,8,10,12,13,14,35 | 0,4 |
| 1 | 0 | 4 | 0 | 8,10,12,13,14,35,43 |
| X |  |  | 4,43 | 2,3 |
| F | Op3’&Op2’&Op1’ | Op3’&Op2 | Op3’&Op1’ | Op3|Op0 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | MemtoReg | RegWrite | MemRead | MemWrite |
| 0 | 0,2,3, 8,10,12,13,14 | 2,4,43 | 0,2,3,4,8,10,12,13,14,43 | 0,2,3,4,8,10,12,13,14,35 |
| 1 | 35 | 0,3,8,10,12,13,14,35 | 35 | 43 |
| X | 4,43 |  |  |  |
| F | Op5 | (Op2’&Op1’)|  ( Op3’&Op0)|  ( Op5’&Op3) | Op5&Op3’ | Op5&Op3 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Branch | Jump | RegDst\_ra | JumptoReg |
| 0 | 0,2,3,8,10,12,13, 14,35,43 | 0,4,8,10,12,13, 14,35,43 | 0,2,8,10,12,13, 14,35 | 0,2,3,4,8,10,12,13, 14,35,43 |
| 1 | 4 | 2,3 | 3 |  |
| X |  |  | 4,43 |  |
| F | Op3’&Op2 | Op5’&Op3’ &Op1 | Op5’&Op3’ &Op0 | \*JR, JALR 處理 |

考慮JR跟JALR後的特殊處理

RegWrite\* = Regwrite & (JumpReg’ | Jalr)

JumptoReg = Op1’ & Op2’ &Op3’ & Funct5’ & Funct3

Jalr = JumptoReg & Funct0

RegDst\_ra\* = RegDst\_ra | Jalr

P.S.

‘ 符號代表negation

& 符號代表AND

| 符號代表OR

\* 符號代表特殊處理後新的值

ALU control

ALU\_ctrl = (ALUOp1) ? R-type\_Ctrl : I-type\_Ctrl

For R-type

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | ADD | SUB | AND | OR | XOR | NOR | SLT | SLL | SRA | SRL | JR | JALR |
| F5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| F4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| F3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| F2 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| F1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| F0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| Output | | | | | | | | | | | | |
| Ctrl3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| Ctrl2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Ctrl1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| Ctrl0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |

(以下數字都是Funct的值)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Ctrl3 | Ctrl2 | Ctrl3 | Ctrl0 |
| 0 | 8,9,32,34,36, 37,38,39,42 | 0,2,3,8,9,32,34,36,37 | 0,2,3,8,9,32,34,38,39 | 0,2,8,9,32,36,38, 42 |
| 1 | 0,2,3 | 38,39,42 | 36,37,42 | 3,34,37,39 |
| X |  |  |  |  |
| F | F3’&F5’ | (F3&F1)| (F2&F1) | (F2&F1’)| (F3&F1) | (F3’&F0)|(F3’&F2’&F1) |

For I-type

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | ADDI | ANDI | ORI | XORI | SLTI | SW | LW |
| Op5 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Op4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Op3 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| Op2 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| Op1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| Op0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| Output | | | | | | | |
| Ctrl3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ctrl2 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| Ctrl1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| Ctrl0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |

(以下數字都是Opcode的值)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Ctrl3 | Ctrl2 | Ctrl3 | Ctrl0 |
| 0 | 8,10,12,13,14,  35,43 | 8,12,13,35,43 | 8,14,35,43 | 8,10,12,14,  35,43 |
| 1 |  | 10,14 | 10,12,13 | 13 |
| X |  |  |  |  |
| F | 0 | Op5’&Op1 | (Op2&Op1’)| (Op5’&Op2’&Op1) | Op5’&Op0 |

ALU

|  |  |
| --- | --- |
| Discription | ALU control signal |
| Add | 0000 |
| Sub | 0001 |
| And | 0010 |
| Or | 0011 |
| Xor | 0100 |
| Nor | 0101 |
| Set less than | 0110 |
| Shift left logical | 1000 |
| Shift right arithmetic | 1001 |
| Shift right logical | 1011 |
| NOP | others |