# 附录A RISC-V指令列表

**Coco Chanel** (1883-1971)香奈儿时装品牌的创始人，她对昂贵的简约的追求塑造了20世纪的时尚。



简约是一切真正优雅的要义。——Coco Chanel，1923

本附录列出了RV32/64I的所有指令、本书中涵盖的所有扩展（RVM、RVA、RVF、RVD、RVC和RVV）以及所有伪指令。每个条目都包括指令名称、操作数、寄存器传输级定义、指令格式类型、中文描述、压缩版本（如果存在），以及一张带有操作码的指令布局图。我们认为这些摘要对于您了解所有的指令已经足够，但如果您想了解更多细节，请参阅RISC-V官方规范[Waterman and Asanovic 2017]。

为了帮助读者在本附录中找到所需的指令，左侧（奇数）页面的标题包含该页顶部的第一条指令，右侧（偶数）页面的标题包含该页底部的最后一条指令。格式类似于字典的标题，有助于您搜索单词所在的页面。例如，下一个偶数页的标题是**AMOADD.W**，这是该页的第一条指令；下一个奇数页的标题是**AMOMINU.D**，这是该页的最后一条指令。如下是你能在这两页中找到的指令：amoadd.w、adoand.d、amoadn.w、amomax.d、amomax.w、amomaxu.d、amomaxu.w、amomin.d、amomin.w和amominu.d。

add rd, rs1, rs2 x[rd] = x[rs1] + x[rs2]

加 *(Add)*. R-type, RV32I and RV64I.

把寄存器x[*rs2*]加到寄存器x[*rs1*]上，结果写入x[*rd*]。忽略算术溢出。

压缩形式：**c.add** rd, rs2; **c.mv** rd, rs2

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000000 | rs2 | rs1 | 000 | Rd | 0110011 |

addi rd, rs1, immediate x[rd] = x[rs1] + sext(immediate)

加立即数*(Add Immediate)*. I-type, RV32I and RV64I.

把符号位扩展的立即数加到寄存器x[*rs1*]上，结果写入x[*rd*]。忽略算术溢出。

压缩形式：**c.li** rd, imm; **c.addi** rd, imm; **c.addi16sp** imm; **c.addi4spn** rd, imm

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| immediate[11:0] | rs1 | 000 | rd | 0010011 |

addiw rd, rs1, immediate x[rd] = sext((x[rs1] + sext(immediate))[31:0])

加立即数字*(Add Word Immediate)*. I-type, RV64I.

把符号位扩展的立即数加到x[*rs1*]，将结果截断为32位，把符号位扩展的结果写入x[*rd*]。忽略算术溢出。

压缩形式：**c.addiw** rd, imm

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| immediate[11:0] | rs1 | 000 | rd | 0011011 |

addw rd, rs1, rs2 x[rd] = sext((x[rs1] + x[rs2])[31:0])

加字*(Add Word)*. R-type, RV64I.

把寄存器x[*rs2*]加到寄存器x[*rs1*]上，将结果截断为32位，把符号位扩展的结果写入x[*rd*]。忽略算术溢出。

压缩形式：**c.addw** rd, rs2

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000000 | rs2 | rs1 | 000 | rd | 0111011 |

amoadd.d rd, rs2, (rs1) x[rd] = AMO64(M[x[rs1]] + x[rs2])

原子加双字*(Atomic Memory Operation: Add Doubleword)*. R-type, RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的双字记为*t*，把这个双字变为*t*+x[*rs2*]，把x[*rd*]设为*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 00000 | aq | rl | rs2 | rs1 | 011 | rd | 0101111 |

amoadd.w rd, rs2, (rs1) x[rd] = AMO32(M[x[rs1]] + x[rs2])

原子加字*(Atomic Memory Operation: Add Word)*. R-type, RV32A and RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的字记为*t*，把这个字变为*t*+x[*rs2*]，把x[*rd*]设为符号位扩展的*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 00000 | aq | rl | rs2 | rs1 | 010 | rd | 0101111 |

amoand.d rd, rs2, (rs1) x[rd] = AMO64(M[x[rs1]] & x[rs2])

原子双字与 *(Atomic Memory Operation: AND Doubleword)*. R-type, RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的双字记为*t*，把这个双字变为t和x[*rs2*]位与的结果，把x[*rd*]设为*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 01100 | aq | rl | rs2 | rs1 | 011 | rd | 0101111 |

amoand.w rd, rs2, (rs1) x[rd] = AMO32(M[x[rs1]] & x[rs2])

原子字与 *(Atomic Memory Operation: AND Word)*. R-type, RV32A and RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的字记为*t*，把这个字变为t和x[*rs2*]位与的结果，把x[*rd*]设为符号位扩展的*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 01100 | aq | rl | rs2 | rs1 | 010 | rd | 0101111 |

amomax.d rd, rs2, (rs1) x[rd] = AMO64(M[x[rs1]] MAX x[rs2])

原子最大双字*(Atomic Memory Operation: Maximum Doubleword)*. R-type, RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的双字记为*t*，把这个双字变为t和x[*rs2*]中较大的一个（用二进制补码比较），把x[*rd*]设为*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 10100 | aq | rl | rs2 | rs1 | 011 | rd | 0101111 |

amomax.w rd, rs2, (rs1) x[rd] = AMO32(M[x[rs1]] MAX x[rs2])

原子最大字*(Atomic Memory Operation: Maximum Word)*. R-type, RV32A and RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的字记为*t*，把这个字变为t和x[*rs2*]中较大的一个（用二进制补码比较），把x[*rd*]设为符号位扩展的*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 10100 | aq | rl | rs2 | rs1 | 010 | rd | 0101111 |

amomaxu.d rd, rs2, (rs1) x[rd] = AMO64(M[x[rs1]] MAXU x[rs2])

原子无符号最大双字*(Atomic Memory Operation: Maximum Doubleword, Unsigned).* R-type, RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的双字记为*t*，把这个双字变为t和x[*rs2*]中较大的一个（用无符号比较），把x[*rd*]设为*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 11100 | aq | rl | rs2 | rs1 | 011 | rd | 0101111 |

amomaxu.w rd, rs2, (rs1) x[rd] = AMO32(M[x[rs1]] MAXU x[rs2])

原子无符号最大字*(Atomic Memory Operation: Maximum Word, Unsigned).* R-type, RV32A and RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的字记为*t*，把这个字变为t和x[*rs2*]中较大的一个（用无符号比较），把x[*rd*]设为符号位扩展的*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 11100 | aq | rl | rs2 | rs1 | 010 | rd | 0101111 |

amomin.d rd, rs2, (rs1) x[rd] = AMO64(M[x[rs1]] MIN x[rs2])

原子最小双字*(Atomic Memory Operation: Minimum Doubleword).* R-type, RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的双字记为*t*，把这个双字变为t和x[*rs2*]中较小的一个（用二进制补码比较），把x[*rd*]设为*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 10000 | aq | rl | rs2 | rs1 | 011 | rd | 0101111 |

amomin.w rd, rs2, (rs1) x[rd] = AMO32(M[x[rs1]] MIN x[rs2])

原子最小字*(Atomic Memory Operation: Minimum Word).* R-type, RV32A and RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的字记为*t*，把这个字变为t和x[*rs2*]中较小的一个（用二进制补码比较），把x[*rd*]设为符号位扩展的*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 10000 | aq | rl | rs2 | rs1 | 010 | rd | 0101111 |

amominu.d rd, rs2,(rs1) x[rd] = AMO64(M[x[rs1]] MINU x[rs2])

原子无符号最小双字*(Atomic Memory Operation: Minimum Doubleword, Unsigned).* R-type, RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的双字记为*t*，把这个双字变为t和x[*rs2*]中较小的一个（用无符号比较），把x[*rd*]设为*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 11000 | aq | rl | rs2 | rs1 | 011 | rd | 0101111 |

amominu.w rd, rs2, (rs1) x[rd] = AMO32(M[x[rs1]] MINU x[rs2])

原子无符号最大字*(Atomic Memory Operation: Minimum Word, Unsigned).* R-type, RV32A and RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的字记为*t*，把这个字变为t和x[*rs2*]中较小的一个（用无符号比较），把x[*rd*]设为符号位扩展的*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 11000 | aq | rl | rs2 | rs1 | 010 | rd | 0101111 |

amoor.d rd, rs2, (rs1) x[rd] = AMO64(M[x[rs1]] | x[rs2])

原子双字或 *(Atomic Memory Operation: OR Doubleword)*. R-type, RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的双字记为*t*，把这个双字变为t和x[*rs2*]位或的结果，把x[*rd*]设为*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 01000 | aq | rl | rs2 | rs1 | 011 | rd | 0101111 |

amoor.w rd, rs2, (rs1) x[rd] = AMO32(M[x[rs1]] | x[rs2])

原子字或 *(Atomic Memory Operation: OR Word)*. R-type, RV32A and RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的字记为*t*，把这个字变为t和x[*rs2*]位或的结果，把x[*rd*]设为符号位扩展的*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 01000 | aq | rl | rs2 | rs1 | 010 | rd | 0101111 |

amoswap.d rd, rs2, (rs1) x[rd] = AMO64(M[x[rs1]] SWAP x[rs2])

原子双字交换 *(Atomic Memory Operation: Swap Doubleword)*. R-type, RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的双字记为*t*，把这个双字变为x[*rs2*]的值，把x[*rd*]设为*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 00001 | aq | rl | rs2 | rs1 | 011 | rd | 0101111 |

amoor.w rd, rs2, (rs1) x[rd] = AMO32(M[x[rs1]] SWAP x[rs2])

原子字交换 *(Atomic Memory Operation: Swap Word)*. R-type, RV32A and RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的字记为*t*，把这个字变为x[*rs2*]的值，把x[*rd*]设为符号位扩展的*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 00001 | aq | rl | rs2 | rs1 | 010 | rd | 0101111 |

amoxor.d rd, rs2, (rs1) x[rd] = AMO64(M[x[rs1]] ^ x[rs2])

原子双字异或 *(Atomic Memory Operation: XOR Doubleword)*. R-type, RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的双字记为*t*，把这个双字变为t和x[*rs2*]按位异或的结果，把x[*rd*]设为*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 00100 | aq | rl | rs2 | rs1 | 011 | rd | 0101111 |

amoxor.w rd, rs2, (rs1) x[rd] = AMO32(M[x[rs1]] ^ x[rs2])

原子字异或 *(Atomic Memory Operation: XOR Word)*. R-type, RV32A and RV64A.

进行如下的原子操作：将内存中地址为x[*rs1*]中的字记为*t*，把这个字变为t和x[*rs2*]按位异或的结果，把x[*rd*]设为符号位扩展的*t*。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 00100 | aq | rl | rs2 | rs1 | 010 | rd | 0101111 |

and rd, rs1, rs2 x[rd] = x[rs1] & x[rs2]

与 *(And)*. R-type, RV32I and RV64I.

将寄存器x[*rs1*]和寄存器x[*rs2*]位与的结果写入x[*rd*]。

压缩形式：**c.and** rd, rs2

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000000 | rs2 | rs1 | 111 | rd | 0110011 |

andi rd, rs1, immediate x[rd] = x[rs1] & sext(immediate)

与立即数 *(And Immediate)*. I-type, RV32I and RV64I.

把符号位扩展的立即数和寄存器x[*rs1*]上的值进行位与，结果写入x[*rd*]。

压缩形式：**c.andi** rd, imm

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| immediate[11:0] | rs1 | 111 | rd | 0010011 |

auipc rd, immediate x[rd] = pc + sext(immediate[31:12] << 12)

*PC*加立即数 *(Add Upper Immediate to PC)*. U-type, RV32I and RV64I.

把符号位扩展的20位（左移12位）立即数加到*pc*上，结果写入x[*rd*]。

31 12 11 7 6 0

|  |  |  |
| --- | --- | --- |
| immediate[31:12] | rd | 0010111 |

beq rs1, rs2, offset if (rs1 == rs2) pc += sext(offset)

相等时分支 *(Branch if Equal)*. B-type, RV32I and RV64I.

若寄存器x[*rs1*]和寄存器x[*rs2*]的值相等，把*pc*的值设为当前值加上符号位扩展的偏移*offset*。

压缩形式：**c.beqz** rs1, offset

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| offset[12|10:5] | rs2 | rs1 | 000 | offset[4:1|11] | 1100011 |

beqz rs1, offset if (rs1 == 0) pc += sext(offset)

等于零时分支 *(Branch if Equal to Zero)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

可视为**beq** rs1, x0, offset.

bge rs1, rs2, offset if (rs1 ≥s rs2) pc += sext(offset)

大于等于时分支 *(Branch if Greater Than or Equal)*. B-type, RV32I and RV64I.

若寄存器x[*rs1*]的值大于等于寄存器x[*rs2*]的值（均视为二进制补码），把*pc*的值设为当前值加上符号位扩展的偏移*offset*。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| offset[12|10:5] | rs2 | rs1 | 101 | offset[4:1|11] | 1100011 |

bgeu rs1, rs2, offset if (rs1 ≥u rs2) pc += sext(offset)

无符号大于等于时分支 *(Branch if Greater Than or Equal, Unsigned)*. B-type, RV32I and RV64I.

若寄存器x[*rs1*]的值大于等于寄存器x[*rs2*]的值（均视为无符号数），把*pc*的值设为当前值加上符号位扩展的偏移*offset*。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| offset[12|10:5] | rs2 | rs1 | 111 | offset[4:1|11] | 1100011 |

bgez rs1, offset if (rs1 ≥s 0) pc += sext(offset)

大于等于零时分支 *(Branch if Greater Than or Equal to Zero)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

可视为**bge** rs1, x0, offset.

bgt rs1, rs2, offset if (rs1 >s rs2) pc += sext(offset)

大于时分支 *(Branch if Greater Than)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

可视为**blt** rs2, rs1, offset.

bgtu rs1, rs2, offset if (rs1 >u rs2) pc += sext(offset)

无符号大于时分支 *(Branch if Greater Than, Unsigned)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

可视为**bltu** rs2, rs1, offset.

bgtz rs1, offset if (rs2 >s 0) pc += sext(offset)

大于零时分支 *(Branch if Greater Than Zero)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

可视为**blt** x0, rs2, offset.

ble rs1, rs2, offset if (rs1 ≤s rs2) pc += sext(offset)

小于等于时分支 *(Branch if Less Than or Equal)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

可视为**bge** rs2, rs1, offset.

bleu rs1, rs2, offset if (rs1 ≤u rs2) pc += sext(offset)

小于等于时分支 *(Branch if Less Than or Equal, Unsigned)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

可视为**bgeu** rs2, rs1, offset.

blez rs2, offset if (rs2 ≤s 0) pc += sext(offset)

小于等于零时分支 *(Branch if Less Than or Equal to Zero)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

可视为**bge** x0, rs2, offset.

blt rs1, rs2, offset if (rs1 <s rs2) pc += sext(offset)

小于时分支 *(Branch if Less Than)*. B-type, RV32I and RV64I.

若寄存器x[*rs1*]的值小于寄存器x[*rs2*]的值（均视为二进制补码），把*pc*的值设为当前值加上符号位扩展的偏移*offset*。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| offset[12|10:5] | rs2 | rs1 | 100 | offset[4:1|11] | 1100011 |

bltz rs2, offset if (rs1 <s 0) pc += sext(offset)

小于零时分支 *(Branch if Less Than Zero)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

可视为**blt** rs1, x0, offset.

bltu rs1, rs2, offset if (rs1 <u rs2) pc += sext(offset)

无符号小于时分支 *(Branch if Less Than, Unsigned)*. B-type, RV32I and RV64I.

若寄存器x[*rs1*]的值小于寄存器x[*rs2*]的值（均视为无符号数），把*pc*的值设为当前值加上符号位扩展的偏移*offset*。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| offset[12|10:5] | rs2 | rs1 | 110 | offset[4:1|11] | 1100011 |

bne rs1, rs2, offset if (rs1 ≠ rs2) pc += sext(offset)

不相等时分支 *(Branch if Not Equal)*. B-type, RV32I and RV64I.

若寄存器x[*rs1*]和寄存器x[*rs2*]的值不相等，把*pc*的值设为当前值加上符号位扩展的偏移*offset*。

压缩形式：**c.bnez** rs1, offset

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| offset[12|10:5] | rs2 | rs1 | 001 | offset[4:1|11] | 1100011 |

bnez rs1, offset if (rs1 ≠ 0) pc += sext(offset)

不等于零时分支 *(Branch if Not Equal to Zero)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

可视为**bne** rs1, x0, offset.

c.add rd, rs2 x[rd] = x[rd] + x[rs2]

加 *(Add)*. RV32IC and RV64IC.

扩展形式为**add** rd, rd, rs2. rd=x0或rs2=x0时非法。

15 13 12 11 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 100 | 1 | rd | rs2 | 10 |

c.addi rd, imm x[rd] = x[rd] + sext(imm)

加立即数 *(Add Immediate)*. RV32IC and RV64IC.

扩展形式为**addi** rd, rd, imm.

15 13 12 11 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 000 | imm[5] | rd | imm[4:0] | 01 |

c.addi16sp imm x[2] = x[2] + sext(imm)

加16倍立即数到栈指针 *(Add Immediate, Scaled by 16, to Stack Pointer)*. RV32IC and RV64IC.

扩展形式为**addi** x2, x2, imm. imm=0时非法。

15 13 12 11 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 011 | imm[9] | 00010 | imm[4|6|8:7|5] | 01 |

c.addi4spn rd’, uimm x[8+rd’] = x[2] + uimm

加4倍立即数到栈指针 *(Add Immediate, Scaled by 4, to Stack Pointer, Nondestructive)*. RV32IC and RV64IC.

扩展形式为**addi** rd, x2, uimm, 其中rd=8+rd’. uimm=0时非法。

15 13 12 5 4 2 1 0

|  |  |  |  |
| --- | --- | --- | --- |
| 000 | uimm[5:4|9:6|2|3] | rd’ | 00 |

c.addiw rd, imm x[rd] = sext((x[rd] + sext(imm))[31:0])

加立即数字 *(Add Word Immediate)*. RV64IC.

扩展形式为**addiw** rd, rd, imm. rd=x0时非法。

15 13 12 11 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 001 | imm[5] | rd | imm[4:0] | 01 |

c.and rd’, rs2’ x[8+rd’] = x[8+rd’] & x[8+rs2’]

与 *(AND)*. RV32IC and RV64IC.

扩展形式为**and** rd, rd, rs2, 其中rd=8+rd’, rs2=8+rs2’.

15 10 9 7 6 5 4 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 100011 | rd’ | 11 | rs2’ | 01 |

c.addw rd’, rs2’ x[8+rd’] = sext((x[8+rd’] + x[8+rs2’])[31:0])

加字 *(Add Word)*. RV64IC.

扩展形式为**addw** rd, rd, rs2, 其中rd=8+rd’, rs2=8+rs2’.

15 10 9 7 6 5 4 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 100111 | rd’ | 01 | rs2’ | 01 |

c.andi rd’, imm x[8+rd’] = x[8+rd’] & sext(imm)

与立即数 *(AND Immediate)*. RV32IC and RV64IC.

扩展形式为**andi** rd, rd, imm, 其中rd=8+rd’.

15 13 12 11 10 9 7 6 2 1 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 100 | imm[5] | 10 | rd’ | imm[4:0] | 01 |

c.beqz rs1’, offset if (x[8+rs1’] == 0) pc += sext(offset)

等于零时分支 *(Branch if Equal to Zero)*. RV32IC and RV64IC.

扩展形式为**beq** rs1, x0, offset, 其中rs1=8+rs1’.

15 13 12 10 9 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 110 | offset[8|4:3] | rs1’ | offset[7:6|2:1|5] | 01 |

c.bnez rs1’, offset if (x[8+rs1’] ≠ 0) pc += sext(offset)

不等于零时分支 *(Branch if Not Equal to Zero)*. RV32IC and RV64IC.

扩展形式为**bne** rs1, x0, offset, 其中rs1=8+rs1’.

15 13 12 10 9 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 111 | offset[8|4:3] | rs1’ | offset[7:6|2:1|5] | 01 |

c.ebreak RaiseException(Breakpoint)

环境断点 *(Environment Breakpoint)*. RV32IC and RV64IC.

扩展形式为**ebreak**.

15 13 12 11 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 100 | 1 | 00000 | 00000 | 10 |

c.fld rd’, uimm(rs1’) f[8+rd’] = M[x[8+rs1’] + uimm][63:0]

浮点双字加载 *(Floating-point Load Doubleword)*. RV32DC and RV64DC.

扩展形式为**fld** rd, uimm(rs1), 其中rd=8+rd’, rs1=8+rs1’.

15 13 12 10 9 7 6 5 4 2 1 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 001 | uimm[5:3] | rs1’ | uimm[7:6] | rd’ | 00 |

c.fldsp rd, uimm(x2) f[rd] = M[x[2] + uimm][63:0]

栈指针相关浮点双字加载 *(Floating-point Load Doubleword, Stack-Pointer Relative)*. RV32DC and RV64DC.

扩展形式为**fld** rd, uimm(x2).

15 13 12 11 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 001 | uimm[5] | rd | uimm[4:3|8:6] | 10 |

c.flw rd’, uimm(rs1’) f[8+rd’] = M[x[8+rs1’] + uimm][31:0]

浮点字加载 *(Floating-point Load Word)*. RV32FC.

扩展形式为**flw** rd, uimm(rs1), 其中rd=8+rd’, rs1=8+rs1’.

15 13 12 10 9 7 6 5 4 2 1 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 011 | uimm[5:3] | rs1’ | uimm[2|6] | rd’ | 00 |

c.flwsp rd, uimm(x2) f[rd] = M[x[2] + uimm][31:0]

栈指针相关浮点字加载 *(Floating-point Load Word, Stack-Pointer Relative)*. RV32FC.

扩展形式为**flw** rd, uimm(x2).

15 13 12 11 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 011 | uimm[5] | rd | uimm[4:2|7:6] | 10 |

c.fsd rs2’, uimm(rs1’) M[x[8+rs1’] + uimm][63:0] = f[8+rs2’]

浮点双字存储 *(Floating-point Store Doubleword)*. RV32DC and RV64DC.

扩展形式为**fsd** rs2, uimm(rs1), 其中rs2=8+rs2’, rs1=8+rs1’.

15 13 12 10 9 7 6 5 4 2 1 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 101 | uimm[5:3] | rs1’ | uimm[7:6] | rs2’ | 00 |

c.fsdsp rs2, uimm(x2) M[x[2] + uimm][63:0] = f[rs2]

栈指针相关浮点双字存储 *(Floating-point Store Doubleword, Stack-Pointer Relative)*. RV32DC and RV64DC.

扩展形式为**fsd** rs2, uimm(x2).

15 13 12 7 6 2 1 0

|  |  |  |  |
| --- | --- | --- | --- |
| 101 | uimm[5:3|8:6] | rs2 | 10 |

c.fsw rs2’, uimm(rs1’) M[x[8+rs1’] + uimm][31:0] = f[8+rs2’]

浮点字存储 *(Floating-point Store Word)*. RV32FC.

扩展形式为**fsw** rs2, uimm(rs1), 其中rs2=8+rs2’, rs1=8+rs1’.

15 13 12 10 9 7 6 5 4 2 1 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 111 | uimm[5:3] | rs1’ | uimm[2|6] | rs2’ | 00 |

c.fswsp rs2, uimm(x2) M[x[2] + uimm][31:0] = f[rs2]

栈指针相关浮点字存储 *(Floating-point Store Word, Stack-Pointer Relative)*. RV32FC.

扩展形式为**fsw** rs2, uimm(x2).

15 13 12 7 6 2 1 0

|  |  |  |  |
| --- | --- | --- | --- |
| 111 | uimm[5:2|7:6] | rs2 | 10 |

c.j offset pc += sext(offset)

跳转 *(Jump)*. RV32IC and RV64IC.

扩展形式为**jal** x0, offset.

15 13 12 2 1 0

|  |  |  |
| --- | --- | --- |
| 101 | offset[11|4|9:8|10|6|7|3:1|5] | 01 |

c.jal offset x[1] = pc+2; pc += sext(offset)

链接跳转 *(Jump and Link)*. RV32IC.

扩展形式为**jal** x1, offset.

15 13 12 2 1 0

|  |  |  |
| --- | --- | --- |
| 001 | offset[11|4|9:8|10|6|7|3:1|5] | 01 |

c.jalr rs1 t = pc+2; pc = x[rs1]; x[1] = t

寄存器链接跳转 *(Jump and Link Register)*. RV32IC and RV64IC.

扩展形式为**jalr** x1, 0(rs1). 当rs1=x0时非法。

15 13 12 11 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 100 | 1 | rs1 | 00000 | 10 |

c.jr rs1 pc = x[rs1]

寄存器跳转 *(Jump Register)*. RV32IC and RV64IC.

扩展形式为**jalr** x0, 0(rs1). 当rs1=x0时非法。

15 13 12 11 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 100 | 0 | rs1 | 00000 | 10 |

c.ld rd’, uimm(rs1’) x[8+rd’] = M[x[8+rs1’] + uimm][63:0]

双字加载 *(Load Doubleword)*. RV64IC.

扩展形式为**ld** rd, uimm(rs1), 其中rd=8+rd’, rs1=8+rs1’.

15 13 12 10 9 7 6 5 4 2 1 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 011 | uimm[5:3] | rs1’ | uimm[7:6] | rd’ | 00 |

c.ldsp rd, uimm(x2) x[rd] = M[x[2] + uimm][63:0]

栈指针相关双字加载 *(Load Doubleword, Stack-Pointer Relative)*. RV64IC.

扩展形式为**ld** rd, uimm(x2). rd=x0时非法。

15 13 12 11 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 011 | uimm[5] | rd | uimm[4:3|8:6] | 10 |

c.li rd, imm x[rd] = sext(imm)

立即数加载 *(Load Immediate)*. RV32IC and RV64IC.

扩展形式为**addi** rd, x0, imm.

15 13 12 11 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 010 | imm[5] | rd | imm[4:0] | 01 |

c.lui rd, imm x[rd] = sext(imm[17:12] << 12)

高位立即数加载 *(Load Upper Immediate)*. RV32IC and RV64IC.

扩展形式为**lui** rd, imm. 当rd=x2或imm=0时非法。

15 13 12 11 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 011 | imm[17] | rd | imm[16:12] | 01 |

c.lw rd’, uimm(rs1’) x[8+rd’] = sext(M[x[8+rs1’] + uimm][31:0])

字加载 *(Load Word)*. RV32IC and RV64IC.

扩展形式为**lw** rd, uimm(rs1), 其中rd=8+rd’, rs1=8+rs1’.

15 13 12 10 9 7 6 5 4 2 1 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 010 | uimm[5:3] | rs1’ | uimm[2|6] | rd’ | 00 |

c.lwsp rd, uimm(x2) x[rd] = sext(M[x[2] + uimm][31:0])

栈指针相关字加载 *(Load Word, Stack-Pointer Relative)*. RV32IC and RV64IC.

扩展形式为**lw** rd, uimm(x2). rd=x0时非法。

15 13 12 11 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 010 | uimm[5] | rd | uimm[4:2|7:6] | 10 |

c.mv rd, rs2 x[rd] = x[rs2]

移动 *(Move)*. RV32IC and RV64IC.

扩展形式为**add** rd, x0, rs2. rs2=x0时非法。

15 13 12 11 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 100 | 0 | rd | rs2 | 10 |

c.or rd’, rs2’ x[8+rd’] = x[8+rd’] | x[8+rs2’]

或 *(OR)*. RV32IC and RV64IC.

扩展形式为**or** rd, rd, rs2, 其中rd=8+rd’, rs2=8+rs2’.

15 10 9 7 6 5 4 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 100011 | rd’ | 10 | rs2’ | 01 |

c.sd rs2’, uimm(rs1’) M[x[8+rs1’] + uimm][63:0] = x[8+rs2’]

双字存储*(Store Doubleword)*. RV64IC.

扩展形式为**sd** rs2, uimm(rs1), 其中rs2=8+rs2’, rs1=8+rs1’.

15 13 12 10 9 7 6 5 4 2 1 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 111 | uimm[5:3] | rs1’ | uimm[7:6] | rs2’ | 00 |

c.sdsp rs2, uimm(x2) M[x[2] + uimm][63:0] = x[rs2]

栈指针相关双字存储 *(Store Doubleword, Stack-Pointer Relative)*. RV64IC.

扩展形式为**sd** rs2, uimm(x2).

15 13 12 7 6 2 1 0

|  |  |  |  |
| --- | --- | --- | --- |
| 111 | uimm[5:3|8:6] | rs2 | 10 |

c.slli rd, uimm x[rd] = x[rd] << uimm

立即数逻辑左移 *(Shift Left Logical Immediate)*. RV32IC and RV64IC.

扩展形式为**slli** rd, rd, uimm.

15 13 12 11 7 6 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 000 | uimm[5] | rd | uimm[4:0] | 10 |

c.srai rd’, uimm x[8+rd’] = x[8+rd’] >>s uimm

立即数算术右移 *(Shift Right Arithmetic Immediate)*. RV32IC and RV64IC.

扩展形式为**srai** rd, rd, uimm, 其中rd=8+rd’.

15 13 12 11 10 9 7 6 2 1 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 100 | uimm[5] | 01 | rd’ | uimm[4:0] | 01 |

c.srli rd’, uimm x[8+rd’] = x[8+rd’] >>u uimm

立即数逻辑右移 *(Shift Right Logical Immediate)*. RV32IC and RV64IC.

扩展形式为**srli** rd, rd, uimm, 其中rd=8+rd’.

15 13 12 11 10 9 7 6 2 1 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 100 | uimm[5] | 00 | rd’ | uimm[4:0] | 01 |

c.sub rd’, rs2’ x[8+rd’] = x[8+rd’] - x[8+rs2’]

减 *(Subtract)*. RV32IC and RV64IC.

扩展形式为**sub** rd, rd, rs2. 其中rd=8+rd’, rs2=8+rs2’. .

15 10 9 7 6 5 4 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 100011 | rd’ | 00 | rs2’ | 01 |

c.subw rd’, rs2’ x[8+rd’] = sext((x[8+rd’] - x[8+rs2’])[31:0])

减字 *(Subtract Word)*. RV64IC.

扩展形式为**subw** rd, rd, rs2. 其中rd=8+rd’, rs2=8+rs2’. .

15 10 9 7 6 5 4 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 100111 | rd’ | 00 | rs2’ | 01 |

c.sw rs2’, uimm(rs1’) M[x[8+rs1’] + uimm][31:0] = x[8+rs2’]

字存储 *(Store Word)*. RV32IC and RV64IC.

扩展形式为**sw** rs2, uimm(rs1), 其中rs2=8+rs2’, rs1=8+rs1’.

15 13 12 10 9 7 6 5 4 2 1 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 110 | uimm[5:3] | rs1’ | uimm[2|6] | rs2’ | 00 |

c.swsp rs2, uimm(x2) M[x[2] + uimm][31:0] = x[rs2]

栈指针相关字存储 *(Store Word, Stack-Pointer Relative)*. RV32IC and RV64IC.

扩展形式为**sw** rs2, uimm(x2).

15 13 12 7 6 2 1 0

|  |  |  |  |
| --- | --- | --- | --- |
| 110 | uimm[5:2|7:6] | rs2 | 10 |

c.xor rd’, rs2’ x[8+rd’] = x[8+rd’] ^ x[8+rs2’]

异或 *(Exclusive-OR)*. RV32IC and RV64IC.

扩展形式为**xor** rd, rd, rs2, 其中rd=8+rd’, rs2=8+rs2’.

15 10 9 7 6 5 4 2 1 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 100011 | rd’ | 01 | rs2’ | 01 |

call rd, symbol x[rd] = pc+8; pc = &symbol

调用 *(Call)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

把下一条指令的地址（*pc*+8）写入x[*rd*]，然后把*pc*设为*symbol*。等同于**auipc** rd, offestHi, 再加上一条**jalr** rd, offsetLo(rd). 若省略了*rd*，默认为x1.

csrr rd, csr x[rd] = CSRs[csr]

读控制状态寄存器 *(Control and Status Register Read)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

把控制状态寄存器*csr*的值写入x[*rd*]，等同于**csrrs** rd, csr, x0.

csrc csr, rs1 CSRs[csr] &= ~x[rs1]

清除控制状态寄存器 *(Control and Status Register Clear)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

对于x[*rs1*]中每一个为1的位，把控制状态寄存器*csr*的的对应位清零，等同于**csrrc** x0, csr, rs1.

csrci csr, zimm[4:0] CSRs[csr] &= ~zimm

立即数清除控制状态寄存器 *(Control and Status Register Clear Immediate)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

对于五位的零扩展的立即数中每一个为1的位，把控制状态寄存器*csr*的的对应位清零，等同于**csrrci** x0, csr, zimm.

csrrc rd, csr, rs1 t = CSRs[csr]; CSRs[csr] = t &~x[rs1]; x[rd] = t

读后清除控制状态寄存器 *(Control and Status Register Read and Clear)*. I-type, RV32I and RV64I.

记控制状态寄存器*csr*中的值为*t。*把*t*和寄存器x[*rs1*]按位与的结果写入*csr*，再把*t*写入x[*rd*]。

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| csr | rs1 | 011 | rd | 1110011 |

csrrci rd, csr, zimm[4:0] t = CSRs[csr]; CSRs[csr] = t &~zimm; x[rd] = t

立即数读后清除控制状态寄存器 *(Control and Status Register Read and Clear Immediate)*. I-type, RV32I and RV64I.

记控制状态寄存器*csr*中的值为*t。*把*t*和五位的零扩展的立即数*zimm*按位与的结果写入*csr*，再把*t*写入x[*rd*]（*csr*寄存器的第5位及更高位不变）。

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| csr | zimm[4:0] | 111 | rd | 1110011 |

csrrs rd, csr, rs1 t = CSRs[csr]; CSRs[csr] = t | x[rs1]; x[rd] = t

读后置位控制状态寄存器 *(Control and Status Register Read and Set)*. I-type, RV32I and RV64I.

记控制状态寄存器*csr*中的值为*t。*把*t*和寄存器x[*rs1*]按位或的结果写入*csr*，再把*t*写入x[*rd*]。

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| csr | rs1 | 010 | rd | 1110011 |

csrrci rd, csr, zimm[4:0] t = CSRs[csr]; CSRs[csr] = t | zimm; x[rd] = t

立即数读后设置控制状态寄存器 *(Control and Status Register Read and Set Immediate)*. I-type, RV32I and RV64I.

记控制状态寄存器*csr*中的值为*t。*把*t*和五位的零扩展的立即数*zimm*按位或的结果写入*csr*，再把*t*写入x[*rd*]（*csr*寄存器的第5位及更高位不变）。

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| csr | zimm[4:0] | 110 | rd | 1110011 |

csrrw rd, csr, zimm[4:0] t = CSRs[csr]; CSRs[csr] = x[rs1]; x[rd] = t

读后写控制状态寄存器 *(Control and Status Register Read and Write)*. I-type, RV32I and RV64I.

记控制状态寄存器*csr*中的值为*t。*把寄存器x[*rs1*]的值写入*csr*，再把*t*写入x[*rd*]。

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| csr | rs1 | 001 | rd | 1110011 |

csrrwi rd, csr, zimm[4:0] x[rd] = CSRs[csr]; CSRs[csr] = zimm

立即数读后写控制状态寄存器 *(Control and Status Register Read and Write Immediate)*. I-type, RV32I and RV64I.

把控制状态寄存器*csr*中的值拷贝到x[*rd*]中，再把五位的零扩展的立即数*zimm*的值写入*csr*。

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| csr | zimm[4:0] | 101 | rd | 1110011 |

csrs csr, rs1 CSRs[csr] |= x[rs1]

置位控制状态寄存器 *(Control and Status Register Set)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

对于x[*rs1*]中每一个为1的位，把控制状态寄存器*csr*的的对应位置位，等同于**csrrs** x0, csr, rs1.

csrsi csr, zimm[4:0] CSRs[csr] |= zimm

立即数置位控制状态寄存器 *(Control and Status Register Set Immediate)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

对于五位的零扩展的立即数中每一个为1的位，把控制状态寄存器*csr*的的对应位清零，等同于**csrrsi** x0, csr, zimm.

csrw csr, rs1 CSRs[csr] = x[rs1]

写控制状态寄存器 *(Control and Status Register Set)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

把寄存器x[*rs1*]中的值写入控制状态寄存器*csr*，等同于**csrrw** x0, csr, rs1.

csrwi csr, zimm[4:0] CSRs[csr] = zimm

立即数写控制状态寄存器 *(Control and Status Register Write Immediate)*. 伪指令(Pesudoinstruction), RV32I and RV64I.

把五位的零扩展的立即数的值写入控制状态寄存器*csr*的，等同于**csrrwi** x0, csr, zimm.

div rd, rs1, rs2 x[rd] = x[rs1] ÷s x[rs2]

除法*(Divide)*. R-type, RV32M and RV64M.

用寄存器x[*rs1*]的值除以寄存器x[*rs2*]的值，向零舍入，将这些数视为二进制补码，把商写入x[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000001 | rs2 | rs1 | 100 | rd | 0110011 |

divu rd, rs1, rs2 x[rd] = x[rs1] ÷u x[rs2]

无符号除法*(Divide, Unsigned)*. R-type, RV32M and RV64M.

用寄存器x[*rs1*]的值除以寄存器x[*rs2*]的值，向零舍入，将这些数视为无符号数，把商写入x[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000001 | rs2 | rs1 | 101 | rd | 0110011 |

divuw rd, rs1, rs2 x[rd] = sext(x[rs1][31:0] ÷u x[rs2][31:0])

无符号字除法*(Divide Word, Unsigned)*. R-type, RV64M.

用寄存器x[*rs1*]的低32位除以寄存器x[*rs2*]的低32位，向零舍入，将这些数视为无符号数，把经符号位扩展的32位商写入x[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000001 | rs2 | rs1 | 101 | rd | 0111011 |

divw rd, rs1, rs2 x[rd] = sext(x[rs1][31:0] ÷s x[rs2][31:0])

字除法*(Divide Word)*. R-type, RV64M.

用寄存器x[*rs1*]的低32位除以寄存器x[*rs2*]的低32位，向零舍入，将这些数视为二进制补码，把经符号位扩展的32位商写入x[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000001 | rs2 | rs1 | 100 | rd | 0111011 |

Ebreak RaiseException(Breakpoint)

环境断点 *(Environment Breakpoint)*. I-type, RV32I and RV64I.

通过抛出断点异常的方式请求调试器。

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 000000000001 | 00000 | 000 | 00000 | 1110011 |

ecall RaiseException(EnvironmentCall)

环境调用 *(Environment Call)*. I-type, RV32I and RV64I.

通过引发环境调用异常来请求执行环境。

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 000000000000 | 00000 | 000 | 00000 | 1110011 |

fabs.d rd, rs1 f[rd] = |f[rs1]|

浮点数绝对值 *(Floating-point Absolute Value)*. 伪指令(Pesudoinstruction), RV32D and RV64D.

把双精度浮点数f[*rs1*]的绝对值写入f[*rd*]。

等同于**fsgnjx.d** rd, rs1, rs1.

fabs.s rd, rs1 f[rd] = |f[rs1]|

浮点数绝对值 *(Floating-point Absolute Value)*. 伪指令(Pesudoinstruction), RV32F and RV64F.

把单精度浮点数f[*rs1*]的绝对值写入f[*rd*]。

等同于**fsgnjx.s** rd, rs1, rs1.

fadd.d rd, rs1, rs2 f [rd] = f [rs1] + f [rs2]

双精度浮点加*(Floating-point Add, Double-Precision)*. R-type, RV32D and RV64D.

把寄存器f[*rs1*]和f[*rs2*]中的双精度浮点数相加，并将舍入后的和写入f[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000001 | rs2 | rs1 | rm | rd | 1010011 |

fadd.s rd, rs1, rs2 f [rd] = f [rs1] + f [rs2]

单精度浮点加*(Floating-point Add, Single-Precision)*. R-type, RV32F and RV64F.

把寄存器f[*rs1*]和f[*rs2*]中的单精度浮点数相加，并将舍入后的和写入f[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000000 | rs2 | rs1 | rm | rd | 1010011 |

fclass.d rd, rs1, rs2 x[rd] = classify*d*(f[rs1])

双精度浮点分类*(Floating-point Classify, Double-Precision)*. R-type, RV32D and RV64D.

把一个表示寄存器f[*rs1*]中双精度浮点数类别的掩码写入x[*rd*]中。关于如何解释写入x[*rd*]的值，请参阅指令**fclass.s**的介绍。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1110001 | 00000 | rs1 | 001 | rd | 1010011 |

fclass.s rd, rs1, rs2 x[rd] = classify*s*(f[rs1])

单精度浮点分类*(Floating-point Classify, Single-Precision)*. R-type, RV32F and RV64F.

把一个表示寄存器f[*rs1*]中单精度浮点数类别的掩码写入x[*rd*]中。x[*rd*]中有且仅有一位被置上，见下表。

|  |  |
| --- | --- |
| x*[rd]*位 | 含义 |
| 0 | f [*rs1*]为。 |
| 1 | f [*rs1*]是负规格化数。 |
| 2 | f [*rs1*]是负的非规格化数。 |
| 3 | f [*rs1*]是-0。 |
| 4 | f [*rs1*]是+0。 |
| 5 | f [*rs1*]是正的非规格化数。 |
| 6 | f [*rs1*]是正的规格化数。 |
| 7 | f [*rs1*]为+。 |
| 8 | f [*rs1*]是信号(signaling)NaN。 |
| 9 | f [*rs1*]是一个安静(quiet)NaN。 |

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1110000 | 00000 | rs1 | 001 | rd | 1010011 |

fcvt.d.l rd, rs1, rs2 f[rd] = f64*s*64(x[rs1])

长整型向双精度浮点转换*(Floating-point Convert to Double from Long)*. R-type, RV64D.

把寄存器x[*rs1*]中的64位二进制补码表示的整数转化为双精度浮点数，再写入f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1101001 | 00010 | rs1 | rm | rd | 1010011 |

fcvt.d.lu rd, rs1, rs2 f[rd] = f64*u*64(x[rs1])

无符号长整型向双精度浮点转换*(Floating-point Convert to Double from Unsigned Long)*. R-type, RV64D.

把寄存器x[*rs1*]中的64位无符号整数转化为双精度浮点数，再写入f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1101001 | 00011 | rs1 | rm | rd | 1010011 |

fcvt.d.s rd, rs1, rs2 f[rd] = f64*f*32(f[rs1])

单精度向双精度浮点转换*(Floating-point Convert to Double from Single)*. R-type, RV32D and RV64D.

把寄存器f[*rs1*]中的单精度浮点数转化为双精度浮点数，再写入f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0100001 | 00000 | rs1 | rm | rd | 1010011 |

fcvt.d.w rd, rs1, rs2 f[rd] = f64*s*32(x[rs1])

字向双精度浮点转换*(Floating-point Convert to Double from Word)*. R-type, RV32D and RV64D.

把寄存器x[*rs1*]中的32位二进制补码表示的整数转化为双精度浮点数，再写入f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1101001 | 00000 | rs1 | rm | rd | 1010011 |

fcvt.d.wu rd, rs1, rs2 f[rd] = f64*u*32(x[rs1])

无符号字向双精度浮点转换*(Floating-point Convert to Double from Unsigned Word)*. R-type, RV32D and RV64D.

把寄存器x[*rs1*]中的32位无符号整数转化为双精度浮点数，再写入f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1101001 | 00001 | rs1 | rm | rd | 1010011 |

fcvt.l.d rd, rs1, rs2 x[rd] = s64*f*64(f[rs1])

双精度浮点向长整型转换*(Floating-point Convert to Long from Double)*. R-type, RV64D.

把寄存器f[*rs1*]中的双精度浮点数转化为64位二进制补码表示的整数，再写入x[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1100001 | 00010 | rs1 | rm | rd | 1010011 |

fcvt.l.s rd, rs1, rs2 x[rd] = s64*f*32(f[rs1])

单精度浮点向长整型转换*(Floating-point Convert to Long from Single)*. R-type, RV64F.

把寄存器f[*rs1*]中的单精度浮点数转化为64位二进制补码表示的整数，再写入x[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1100000 | 00010 | rs1 | rm | rd | 1010011 |

fcvt.lu.d rd, rs1, rs2 x[rd] = u64*f*64(f[rs1])

双精度浮点向无符号长整型转换*(Floating-point Convert to Unsigned Long from Double)*. R-type, RV64D.

把寄存器f[*rs1*]中的双精度浮点数转化为64位无符号整数，再写入x[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1100001 | 00011 | rs1 | rm | rd | 1010011 |

fcvt.lu.s rd, rs1, rs2 x[rd] = u64*f*32(f[rs1])

单精度浮点向无符号长整型转换*(Floating-point Convert to Unsigned Long from Single)*. R-type, RV64F.

把寄存器f[*rs1*]中的单精度浮点数转化为64位二进制补码表示的整数，再写入x[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1100000 | 00011 | rs1 | rm | rd | 1010011 |

fcvt.s.d rd, rs1, rs2 f[rd] = f32*f*64(f[rs1])

双精度向单精度浮点转换*(Floating-point Convert to Single from Double)*. R-type, RV32D and RV64D.

把寄存器f[*rs1*]中的双精度浮点数转化为单精度浮点数，再写入f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0100000 | 00001 | rs1 | rm | rd | 1010011 |

fcvt.s.l rd, rs1, rs2 f[rd] = f32*s*64(x[rs1])

长整型向单精度浮点转换*(Floating-point Convert to Single from Long)*. R-type, RV64F.

把寄存器x[*rs1*]中的64位二进制补码表示的整数转化为单精度浮点数，再写入f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1101000 | 00010 | rs1 | rm | rd | 1010011 |

fcvt.s.lu rd, rs1, rs2 f[rd] = f32*u*64(x[rs1])

无符号长整型向单精度浮点转换*(Floating-point Convert to Single from Unsigned Long)*. R-type, RV64F.

把寄存器x[*rs1*]中的64位的无符号整数转化为单精度浮点数，再写入f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1101000 | 00011 | rs1 | rm | rd | 1010011 |

fcvt.s.w rd, rs1, rs2 f[rd] = f32*s*32(x[rs1])

字向单精度浮点转换*(Floating-point Convert to Single from Word)*. R-type, RV32F and RV64F.

把寄存器x[*rs1*]中的32位二进制补码表示的整数转化为单精度浮点数，再写入f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1101000 | 00000 | rs1 | rm | rd | 1010011 |

fcvt.s.wu rd, rs1, rs2 f[rd] = f32*u*32(x[rs1])

无符号字向单精度浮点转换*(Floating-point Convert to Single from Unsigned Word)*. R-type, RV32F and RV64F.

把寄存器x[*rs1*]中的32位无符号整数转化为单精度浮点数，再写入f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1101000 | 00001 | rs1 | rm | rd | 1010011 |

fcvt.w.d rd, rs1, rs2 x[rd] = sext(s32*f*64(f[rs1]))

双精度浮点向字转换*(Floating-point Convert to Word from Double)*. R-type, RV32D and RV64D.

把寄存器f[*rs1*]中的双精度浮点数转化为32位二进制补码表示的整数，再写入x[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1100001 | 00000 | rs1 | rm | rd | 1010011 |

fcvt.wu.d rd, rs1, rs2 x[rd] = sext(u32*f*64(f[rs1]))

双精度浮点向无符号字转换*(Floating-point Convert to Unsigned Word from Double)*. R-type, RV32D and RV64D.

把寄存器f[*rs1*]中的双精度浮点数转化为32位无符号整数，再写入x[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1100001 | 00001 | rs1 | rm | rd | 1010011 |

fcvt.w.s rd, rs1, rs2 x[rd] = sext(s32*f*32(f[rs1]))

单精度浮点向字转换*(Floating-point Convert to Word from Single)*. R-type, RV32F and RV64F.

把寄存器f[*rs1*]中的单精度浮点数转化为32位二进制补码表示的整数，再写入x[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1100000 | 00000 | rs1 | rm | rd | 1010011 |

fcvt.wu.s rd, rs1, rs2 x[rd] = sext(u32*f*32(f[rs1]))

单精度浮点向无符号字转换*(Floating-point Convert to Unsigned Word from Single)*. R-type, RV32F and RV64F.

把寄存器f[*rs1*]中的单精度浮点数转化为32位无符号整数，再写入x[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1100000 | 00001 | rs1 | rm | rd | 1010011 |

fdiv.d rd, rs1, rs2 f[rd] = f[rs1] ÷ f[rs2]

双精度浮点除法*(Floating-point Divide, Double-Precision)*. R-type, RV32D and RV64D.

把寄存器f[*rs1*]和f[*rs2*]中的双精度浮点数相除，并将舍入后的商写入f[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0001101 | rs2 | rs1 | rm | rd | 1010011 |

fdiv.s rd, rs1, rs2 f[rd] = f[rs1] ÷ f[rs2]

单精度浮点除法*(Floating-point Divide, Single-Precision)*. R-type, RV32F and RV64F.

把寄存器f[*rs1*]和f[*rs2*]中的单精度浮点数相除，并将舍入后的商写入f[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0001100 | rs2 | rs1 | rm | rd | 1010011 |

fence pred, succ Fence(pred, succ)

同步内存和I/O*(Fence Memory and I/O)*. I-type, RV32I and RV64I.

在后续指令中的内存和I/O访问对外部（例如其他线程）可见之前，使这条指令之前的内存及I/O访问对外部可见。比特中的第3,2,1和0位分别对应于设备输入，设备输出，内存读写。例如**fence** r, rw，将前面读取与后面的读取和写入排序，使用*pred* = 0010和*succ* = 0011进行编码。如果省略了参数，则表示**fence** iorw, iorw，即对所有访存请求进行排序。

31 28 27 24 23 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 0000 | pred | succ | 00000 | 000 | 00000 | 0001111 |

fence.i Fence(Store, Fetch)

同步指令流*(Fence Instruction Stream)*. I-type, RV32I and RV64I.

使对内存指令区域的读写，对后续取指令可见。

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 000000000000 | 00000 | 001 | 00000 | 0001111 |

feq.d rd, rs1, rs2 x[rd] = f[rs1] == f[rs2]

双精度浮点相等*(Floating-point Equals, Double-Precision)*. R-type, RV32D and RV64D.

若寄存器f[*rs1*]和f[*rs2*]中的双精度浮点数相等，则在x[*rd*]中写入1，反之写0。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1010001 | rs2 | rs1 | 010 | rd | 1010011 |

feq.s rd, rs1, rs2 x[rd] = f[rs1] == f[rs2]

单精度浮点相等*(Floating-point Equals, Single-Precision)*. R-type, RV32F and RV64F.

若寄存器f[*rs1*]和f[*rs2*]中的单精度浮点数相等，则在x[*rd*]中写入1，反之写0。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1010000 | rs2 | rs1 | 010 | rd | 1010011 |

fld rd, offset(rs1) f[rd] = M[x[rs1] + sext(offset)][63:0]

浮点加载双字*(Floating-point Load Doubleword)*. I-type, RV32D and RV64D.

从内存地址x[*rs1*] + *sign-extend*(*offset*)中取双精度浮点数，并写入f[*rd*]。

压缩形式：**c.fldsp** rd, offset; **c.fld** rd, offset(rs1)

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| offset[11:0] | rs1 | 011 | rd | 0000111 |

fle.d rd, rs1, rs2 x[rd] = f[rs1] ≤ f[rs2]

双精度浮点小于等于*(Floating-point Less Than or Equal, Double-Precision)*. R-type, RV32D and RV64D.

若寄存器f[*rs1*]中的双精度浮点数小于等于f[*rs2*]中的双精度浮点数，则在x[*rd*]中写入1，反之写0。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1010001 | rs2 | rs1 | 000 | rd | 1010011 |

fle.s rd, rs1, rs2 x[rd] = f[rs1] ≤ f[rs2]

单精度浮点小于等于*(Floating-point Less Than or Equal, Single-Precision)*. R-type, RV32F and RV64F.

若寄存器f[*rs1*]中的单精度浮点数小于等于f[*rs2*]中的单精度浮点数，则在x[*rd*]中写入1，反之写0。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1010000 | rs2 | rs1 | 000 | rd | 1010011 |

fle.d rd, rs1, rs2 x[rd] = f[rs1] < f[rs2]

双精度浮点小于 *(Floating-point Less Than, Double-Precision)*. R-type, RV32D and RV64D.

若寄存器f[*rs1*]中的双精度浮点数小于f[*rs2*]中的双精度浮点数，则在x[*rd*]中写入1，反之写0。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1010001 | rs2 | rs1 | 001 | rd | 1010011 |

fle.s rd, rs1, rs2 x[rd] = f[rs1] < f[rs2]

单精度浮点小于 *(Floating-point Less Than, Single-Precision)*. R-type, RV32F and RV64F.

若寄存器f[*rs1*]中的单精度浮点数小于f[*rs2*]中的单精度浮点数，则在x[*rd*]中写入1，反之写0。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1010000 | rs2 | rs1 | 001 | rd | 1010011 |

flw rd, offset(rs1) f[rd] = M[x[rs1] + sext(offset)][31:0]

浮点加载字*(Floating-point Load Word)*. I-type, RV32F and RV64F.

从内存地址x[*rs1*] + *sign-extend*(*offset*)中取单精度浮点数，并写入f[*rd*]。

压缩形式：**c.flwsp** rd, offset; **c.flw** rd, offset(rs1)

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| offset[11:0] | rs1 | 010 | rd | 0000111 |

fmadd.d rd, rs1, rs2, rs3 f[rd] = f[rs1]×f[rs2]+f[rs3]

双精度浮点乘加*(Floating-point Fused Multiply-Add, Double-Precision)*. R4-type, RV32D and RV64D.

把寄存器f[*rs1*]和f[*rs2*]中的双精度浮点数相乘，并将未舍入的积和寄存器f[*rs3*]中的双精度浮点数相加，将舍入后的双精度浮点数写入f[*rd*]。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| rs3 | 01 | rs2 | rs1 | rm | rd | 1000011 |

fmadd.s rd, rs1, rs2, rs3 f[rd] = f[rs1]×f[rs2]+f[rs3]

单精度浮点乘加*(Floating-point Fused Multiply-Add, Single-Precision)*. R4-type, RV32F and RV64F.

把寄存器f[*rs1*]和f[*rs2*]中的单精度浮点数相乘，并将未舍入的积和寄存器f[*rs3*]中的单精度浮点数相加，将舍入后的单精度浮点数写入f[*rd*]。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| rs3 | 00 | rs2 | rs1 | rm | rd | 1000011 |

fmax.d rd, rs1, rs2 f[rd] = max(f[rs1], f[rs2])

双精度浮点最大值*(Floating-point Maximum, Double-Precision)*. R-type, RV32D and RV64D.

把寄存器f[*rs1*]和f[*rs2*]中的双精度浮点数中的较大值写入f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0010101 | rs2 | rs1 | 001 | rd | 1010011 |

fmax.s rd, rs1, rs2 f[rd] = max(f[rs1], f[rs2])

单精度浮点最大值*(Floating-point Maximum, Single-Precision)*. R-type, RV32F and RV64F.

把寄存器f[*rs1*]和f[*rs2*]中的单精度浮点数中的较大值写入f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0010100 | rs2 | rs1 | 001 | rd | 1010011 |

fmin.d rd, rs1, rs2 f[rd] = min(f[rs1], f[rs2])

双精度浮点最小值*(Floating-point Minimum, Double-Precision)*. R-type, RV32D and RV64D.

把寄存器f[*rs1*]和f[*rs2*]中的双精度浮点数中的较小值写入f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0010101 | rs2 | rs1 | 000 | rd | 1010011 |

fmin.s rd, rs1, rs2 f[rd] = min(f[rs1], f[rs2])

单精度浮点最小值*(Floating-point Minimum, Single-Precision)*. R-type, RV32F and RV64F.

把寄存器f[*rs1*]和f[*rs2*]中的单精度浮点数中的较小值写入f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0010100 | rs2 | rs1 | 000 | rd | 1010011 |

fmsub.d rd, rs1, rs2, rs3 f[rd] = f[rs1]×f[rs2]-f[rs3]

双精度浮点乘减*(Floating-point Fused Multiply-Subtract, Double-Precision)*. R4-type, RV32D and RV64D.

把寄存器f[*rs1*]和f[*rs2*]中的双精度浮点数相乘，并将未舍入的积减去寄存器f[*rs3*]中的双精度浮点数，将舍入后的双精度浮点数写入f[*rd*]。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| rs3 | 01 | rs2 | rs1 | rm | rd | 1000111 |

fmsub.s rd, rs1, rs2, rs3 f[rd] = f[rs1]×f[rs2]-f[rs3]

单精度浮点乘减*(Floating-point Fused Multiply-Subtarct, Single-Precision)*. R4-type, RV32F and RV64F.

把寄存器f[*rs1*]和f[*rs2*]中的单精度浮点数相乘，并将未舍入的积减去寄存器f[*rs3*]中的单精度浮点数，将舍入后的单精度浮点数写入f[*rd*]。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| rs3 | 00 | rs2 | rs1 | rm | rd | 1000111 |

fmul.d rd, rs1, rs2 f[rd] = f[rs1] × f[rs2]

双精度浮点乘*(Floating-point Multiply, Double-Precision)*. R-type, RV32D and RV64D.

把寄存器f[*rs1*]和f[*rs2*]中的双精度浮点数相乘，将舍入后的双精度结果写入f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0001001 | rs2 | rs1 | rm | rd | 1010011 |

fmul.s rd, rs1, rs2 f[rd] = f[rs1] × f[rs2]

单精度浮点乘*(Floating-point Multiply, Single-Precision)*. R-type, RV32F and RV64F.

把寄存器f[*rs1*]和f[*rs2*]中的单精度浮点数相乘，将舍入后的单精度结果写入f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0001000 | rs2 | rs1 | rm | rd | 1010011 |

fmv.d rd, rs1 f[rd] = f[rs1]

双精度浮点移动 *(Floating-point Move)*. 伪指令(Pesudoinstruction), RV32D and RV64D.

把寄存器f[*rs1*]中的双精度浮点数复制到f[*rd*]中，等同于**fsgnj.d** rd, rs1, rs1.

fmv.d.x rd, rs1, rs2 f[rd] = x[rs1][63:0]

双精度浮点移动*(Floating-point Move Doubleword from Integer)*. R-type, RV64D.

把寄存器x[*rs1*]中的双精度浮点数复制到f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1111001 | 00000 | rs1 | 000 | rd | 1010011 |

fmv.s rd, rs1 f[rd] = f[rs1]

单精度浮点移动 *(Floating-point Move)*. 伪指令(Pesudoinstruction), RV32F and RV64F.

把寄存器f[*rs1*]中的单精度浮点数复制到f[*rd*]中，等同于**fsgnj.s** rd, rs1, rs1.

fmv.d.x rd, rs1, rs2 f[rd] = x[rs1][31:0]

单精度浮点移动*(Floating-point Move Word from Integer)*. R-type, RV32F and RV64F.

把寄存器x[*rs1*]中的单精度浮点数复制到f[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1111000 | 00000 | rs1 | 000 | rd | 1010011 |

fmv.x.d rd, rs1, rs2 x[rd] = f[rs1][63:0]

双精度浮点移动*(Floating-point Move Doubleword to Integer)*. R-type, RV64D.

把寄存器f[*rs1*]中的双精度浮点数复制到x[*rd*]中。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1110001 | 00000 | rs1 | 000 | rd | 1010011 |

fmv.x.w rd, rs1, rs2 x[rd] = sext(f[rs1][31:0])

单精度浮点移动*(Floating-point Move Word to Integer)*. R-type, RV32F and RV64F.

把寄存器f[*rs1*]中的单精度浮点数复制到x[*rd*]中，对于RV64F，将结果进行符号扩展。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1110000 | 00000 | rs1 | 000 | rd | 1010011 |

fneg.d rd, rs1 f[rd] = -f[rs1]

双精度浮点取反 *(Floating-point Negate)*. 伪指令(Pesudoinstruction), RV32D and RV64D.

把寄存器f[*rs1*]中的双精度浮点数取反后写入f[*rd*]中，等同于**fsgnjn.d** rd, rs1, rs1.

fneg.s rd, rs1 f[rd] = -f[rs1]

单精度浮点取反 *(Floating-point Negate)*. 伪指令(Pesudoinstruction), RV32F and RV64F.

把寄存器f[*rs1*]中的单精度浮点数取反后写入f[*rd*]中，等同于**fsgnjn.s** rd, rs1, rs1.

fnmadd.d rd, rs1, rs2, rs3 f[rd] = f[rs1]×f[rs2]+f[rs3]

双精度浮点乘取反加*(Floating-point Fused Negative Multiply-Add, Double-Precision)*. R4-type, RV32D and RV64D.

把寄存器f[*rs1*]和f[*rs2*]中的双精度浮点数相乘，将结果取反，并将未舍入的积和寄存器f[*rs3*]中的双精度浮点数相加，将舍入后的双精度浮点数写入f[*rd*]。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| rs3 | 01 | rs2 | rs1 | rm | rd | 1001111 |

fnmadd.s rd, rs1, rs2, rs3 f[rd] = -f[rs1]\_f[rs2]-f[rs3]

单精度浮点乘取反加*(Floating-point Fused Negative Multiply-Add, Single-Precision)*. R4-type, RV32F and RV64F.

把寄存器f[*rs1*]和f[*rs2*]中的单精度浮点数相乘，将结果取反，并将未舍入的积和寄存器f[*rs3*]中的单精度浮点数相加，将舍入后的单精度浮点数写入f[*rd*]。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| rs3 | 00 | rs2 | rs1 | rm | rd | 1001111 |

fnmsub.d rd, rs1, rs2, rs3 f[rd] = -f[rs1]\_f[rs2]+f[rs3]

双精度浮点乘取反减*(Floating-point Fused Negative Multiply-Subtract, Double-Precision)*. R4-type, RV32D and RV64D.

把寄存器f[*rs1*]和f[*rs2*]中的双精度浮点数相乘，将结果取反，并将未舍入的积减去寄存器f[*rs3*]中的双精度浮点数，将舍入后的双精度浮点数写入f[*rd*]。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| rs3 | 01 | rs2 | rs1 | rm | rd | 1001011 |

fnmsub.s rd, rs1, rs2, rs3 f[rd] = -f[rs1]×f[rs2]+f[rs3]

单精度浮点乘取反减*(Floating-point Fused Negative Multiply-Subtract, Single-Precision)*. R4-type, RV32F and RV64F.

把寄存器f[*rs1*]和f[*rs2*]中的单精度浮点数相乘，将结果取反，并将未舍入的积减去寄存器f[*rs3*]中的单精度浮点数，将舍入后的单精度浮点数写入f[*rd*]。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| rs3 | 00 | rs2 | rs1 | rm | rd | 1001011 |

frcsr rd x[rd] = CSRs[fcsr]

浮点读控制状态寄存器 *(Floating-point Read Control and Status Register)*. 伪指令(Pseudoinstruction), RV32F and RV64F.

把浮点控制状态寄存器的值写入x[*rd*]，等同于**csrrs** rd, fcsr, x0.

frflags rd x[rd] = CSRs[fflags]

浮点读异常标志 *(Floating-point Read Exception Flags)*. 伪指令(Pseudoinstruction), RV32F and RV64F.

把浮点异常标志的值写入x[*rd*]，等同于**csrrs** rd, fflags, x0.

frrm rd x[rd] = CSRs[frm]

浮点读舍入模式 *(Floating-point Read Rounding Mode)*. 伪指令(Pseudoinstruction), RV32F and RV64F.

把浮点舍入模式的值写入x[*rd*]，等同于**csrrs** rd, frm, x0.

fscsr rd, rs1 t = CSRs[fcsr]; CSRs[fcsr] = x[rs1]; x[rd] = t

浮点换出控制状态寄存器 *(Floating-point Swap Control and Status Register)*. 伪指令(Pseudoinstruction), RV32F and RV64F.

把寄存器x[*rs1*]的值写入浮点控制状态寄存器，并将浮点控制状态寄存器的原值写入x[*rd*]，等同于**csrrw** rd, fcsr, rs1。*rd*默认为x0。

fsd rs2, offset(rs1) M[x[rs1] + sext(offset)] = f[rs2][63:0]

双精度浮点存储*(Floating-point Store Doubleword)*. S-type, RV32D and RV64D.

将寄存器f[*rs2*]中的双精度浮点数存入内存地址x[*rs1*] + *sign-extend*(*offset*)中。

31 25 24 20 19 15 14 12 11 7 6 0

压缩形式：**c.fsdsp** rs2, offset; **c.fsd** rs2, offset(rs1)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| offset[11:5] | rs2 | rs1 | 011 | offset[4:0] | 0100111 |

fsflags rd, rs1 t = CSRs[fflags]; CSRs[fflags] = x[rs1]; x[rd] = t

浮点换出异常标志 *(Floating-point Swap Exception Flags)*. 伪指令(Pseudoinstruction), RV32F and RV64F.

把寄存器x[*rs1*]的值写入浮点异常标志寄存器，并将浮点异常标志寄存器的原值写入x[*rd*]，等同于**csrrw** rd, fflags, rs1。*rd*默认为x0。

fsgnj.d rd, rs1, rs2 f[rd] = {f[rs2][63], f[rs1][62:0]}

双精度浮点符号注入*(Floating-point Sign Inject, Double-Precision)*. R-type, RV32D and RV64D.

用f[*rs1*]指数和有效数以及f[*rs2*]的符号的符号位，来构造一个新的双精度浮点数，并将其写入f[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0010001 | rs2 | rs1 | 000 | rd | 1010011 |

fsgnj.s rd, rs1, rs2 f[rd] = {f[rs2][31], f[rs1][30:0]}

单精度浮点符号注入*(Floating-point Sign Inject, Single-Precision)*. R-type, RV32F and RV64F.

用f[*rs1*]指数和有效数以及f[*rs2*]的符号的符号位，来构造一个新的单精度浮点数，并将其写入f[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0010000 | rs2 | rs1 | 000 | rd | 1010011 |

fsgnjn.d rd, rs1, rs2 f[rd] = {~f[rs2][63], f[rs1][62:0]}

双精度浮点符号取反注入*(Floating-point Sign Inject-Negate, Double-Precision)*. R-type, RV32D and RV64D.

用f[*rs1*]指数和有效数以及f[*rs2*]的符号的符号位取反，来构造一个新的双精度浮点数，并将其写入f[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0010001 | rs2 | rs1 | 001 | rd | 1010011 |

fsgnjn.s rd, rs1, rs2 f[rd] = {~f[rs2][31], f[rs1][30:0]}

单精度浮点符号取反注入*(Floating-point Sign Inject-Negate, Single-Precision)*. R-type, RV32F and RV64F.

用f[*rs1*]指数和有效数以及f[*rs2*]的符号的符号位取反，来构造一个新的单精度浮点数，并将其写入f[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0010000 | rs2 | rs1 | 001 | rd | 1010011 |

fsgnjx.d rd, rs1, rs2 f[rd] = {f[rs1][63] ^ f[rs2][63], f[rs1][62:0]}

双精度浮点符号异或注入*(Floating-point Sign Inject-XOR, Double-Precision)*. R-type, RV32D and RV64D.

用f[*rs1*]指数和有效数以及f[*rs1*]和f[*rs2*]的符号的符号位异或，来构造一个新的双精度浮点数，并将其写入f[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0010001 | rs2 | rs1 | 010 | rd | 1010011 |

fsgnjx.s rd, rs1, rs2 f[rd] = {f[rs1][31] ^ f[rs2][31], f[rs1][30:0]}

单精度浮点符号异或注入*(Floating-point Sign Inject-XOR, Single-Precision)*. R-type, RV32F and RV64F.

用f[*rs1*]指数和有效数以及f[*rs1*]和f[*rs2*]的符号的符号位异或，来构造一个新的单精度浮点数，并将其写入f[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0010000 | rs2 | rs1 | 010 | rd | 1010011 |

fsqrt.d rd, rs1, rs2 f[rd] =

双精度浮点平方根*(Floating-point Square Root, Double-Precision)*. R-type, RV32D and RV64D.

将f[*rs1*]中的双精度浮点数的平方根舍入和写入f[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0101101 | 00000 | rs1 | rm | rd | 1010011 |

fsqrt.s rd, rs1, rs2 f[rd] =

单精度浮点平方根*(Floating-point Square Root, Single-Precision)*. R-type, RV32F and RV64F.

将f[*rs1*]中的单精度浮点数的平方根舍入和写入f[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0101100 | 00000 | rs1 | rm | rd | 1010011 |

fsrm rd, rs1 t = CSRs[frm]; CSRs[frm] = x[rs1]; x[rd] = t

浮点换出舍入模式 *(Floating-point Swap Rounding Mode)*. 伪指令(Pseudoinstruction), RV32F and RV64F.

把寄存器x[*rs1*]的值写入浮点舍入模式寄存器，并将浮点舍入模式寄存器的原值写入x[*rd*]，等同于**csrrw** rd, frm, rs1。*rd*默认为x0。

fsub.d rd, rs1, rs2 f[rd] = f[rs1] - f[rs2]

双精度浮点减*(Floating-point Subtract, Double-Precision)*. R-type, RV32D and RV64D.

把寄存器f[*rs1*]和f[*rs2*]中的双精度浮点数相减，并将舍入后的差写入f[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000101 | rs2 | rs1 | rm | rd | 1010011 |

fsub.s rd, rs1, rs2 f[rd] = f[rs1] - f[rs2]

单精度浮点减*(Floating-point Subtract, Single-Precision)*. R-type, RV32F and RV64F.

把寄存器f[*rs1*]和f[*rs2*]中的单精度浮点数相减，并将舍入后的差写入f[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000100 | rs2 | rs1 | rm | rd | 1010011 |

fsw rs2, offset(rs1) M[x[rs1] + sext(offset)] = f[rs2][31:0]

单精度浮点存储*(Floating-point Store Word)*. S-type, RV32F and RV64F.

将寄存器f[*rs2*]中的单精度浮点数存入内存地址x[*rs1*] + *sign-extend*(*offset*)中。

31 25 24 20 19 15 14 12 11 7 6 0

压缩形式：**c.fswsp** rs2, offset; **c.fsw** rs2, offset(rs1)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| offset[11:5] | rs2 | rs1 | 010 | offset[4:0] | 0100111 |

j offset pc += sext(offset)

跳转 *(Jump)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

把*pc*设置为当前值加上符号位扩展的*offset*，等同于**jal** x0, offset.

jal rd, offset x[rd] = pc+4; pc += sext(offset)

跳转并链接 *(Jump and Link)*. J-type, RV32I and RV64I.

把下一条指令的地址(*pc+4*)，然后把*pc*设置为当前值加上符号位扩展的*offset*。*rd*默认为x1。

压缩形式：**c.j** offset; **c.jal** offset

31 12 11 7 6 0

|  |  |  |
| --- | --- | --- |
| offset[20|10:1|11|19:12] | rd | 1101111 |

jalr rd, offset(rs1) t =pc+4; pc=(x[rs1]+sext(offset))&~1; x[rd]=t

跳转并寄存器链接 *(Jump and Link Register)*. I-type, RV32I and RV64I.

把*pc*设置为x[*rs1*] + *sign-extend*(*offset*)，把计算出的地址的最低有效位设为0，并将原*pc+4*的值写入f[*rd*]。*rd*默认为x1。

压缩形式：**c.jr** rs1; **c.jalr** rs1

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| offset[11:0] | rs1 | 010 | rd | 1100111 |

jr rs1 pc = x[rs1]

寄存器跳转 *(Jump Register)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

把*pc*设置为x[*rs1*]，等同于**jalr** x0, 0(rs1)。

la rd, symbol x[rd] = &symbol

地址加载 *(Load Address)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

将*symbol*的地址加载到x[*rd*]中。当编译位置无关的代码时，它会被扩展为对全局偏移量表(Global Offset Table)的加载。对于RV32I，等同于执行**auipc** rd, offsetHi，然后是**lw** rd， offsetLo(rd);对于RV64I，则等同于**auipc** rd，offsetHi和**ld** rd, offsetLo(rd)。如果offset过大，开始的算加载地址的指令会变成两条，先是**auipc** rd, offsetHi然后是**addi** rd, rd, offsetLo。

lb rd, offset(rs1) x[rd] = sext(M[x[rs1] + sext(offset)][7:0])

字节加载 *(Load Byte)*. I-type, RV32I and RV64I.

从地址x[*rs1*] + *sign-extend*(*offset*)读取一个字节，经符号位扩展后写入x[*rd*]。

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| offset[11:0] | rs1 | 000 | rd | 0000011 |

lbu rd, offset(rs1) x[rd] = M[x[rs1] + sext(offset)][7:0]

无符号字节加载 *(Load Byte, Unsigned)*. I-type, RV32I and RV64I.

从地址x[*rs1*] + *sign-extend*(*offset*)读取一个字节，经零扩展后写入x[*rd*]。

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| offset[11:0] | rs1 | 100 | rd | 0000011 |

ld rd, offset(rs1) x[rd] = M[x[rs1] + sext(offset)][63:0]

双字加载 *(Load Doubleword)*. I-type, RV32I and RV64I.

从地址x[*rs1*] + *sign-extend*(*offset*)读取八个字节，写入x[*rd*]。

压缩形式：**c.ldsp** rd, offset; **c.ld** rd, offset(rs1)

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| offset[11:0] | rs1 | 011 | rd | 0000011 |

lh rd, offset(rs1) x[rd] = sext(M[x[rs1] + sext(offset)][15:0])

半字加载 *(Load Halfword)*. I-type, RV32I and RV64I.

从地址x[*rs1*] + *sign-extend*(*offset*)读取两个字节，经符号位扩展后写入x[*rd*]。

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| offset[11:0] | rs1 | 001 | rd | 0000011 |

lhu rd, offset(rs1) x[rd] = M[x[rs1] + sext(offset)][15:0]

无符号半字加载 *(Load Halfword, Unsigned)*. I-type, RV32I and RV64I.

从地址x[*rs1*] + *sign-extend*(*offset*)读取两个字节，经零扩展后写入x[*rd*]。

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| offset[11:0] | rs1 | 101 | rd | 0000011 |

li rd, immediate x[rd] = immediate

立即数加载 *(Load Immediate)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

使用尽可能少的指令将常量加载到x[*rd*]中。在RV32I中，它等同于执行**lui**和/或**addi**；对于RV64I，会扩展为这种指令序列**lui, addi, slli, addi, slli, addi ,slli, addi。**

lla rd, symbol x[rd] = &symbol

本地地址加载 *(Load Local Address)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

将*symbol*的地址加载到x[*rd*]中。等同于执行**auipc** rd, offsetHi，然后是**addi** rd, rd, offsetLo。

lr.d rd, (rs1) x[rd] = LoadReserved64(M[x[rs1]])

加载保留双字*(Load-Reserved Doubleword)*. R-type, RV64A.

从内存中地址为x[*rs1*]中加载八个字节，写入x[*rd*]，并对这个内存双字注册保留。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 00010 | aq | rl | 00000 | rs1 | 011 | rd | 0101111 |

lr.w rd, (rs1) x[rd] = LoadReserved32(M[x[rs1]])

加载保留字*(Load-Reserved Word)*. R-type, RV32A and RV64A.

从内存中地址为x[*rs1*]中加载四个字节，符号位扩展后写入x[*rd*]，并对这个内存字注册保留。

31 27 26 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 00010 | aq | rl | 00000 | rs1 | 010 | rd | 0101111 |

lw rd, offset(rs1) x[rd] = sext(M[x[rs1] + sext(offset)][31:0])

字加载 *(Load Word)*. I-type, RV32I and RV64I.

从地址x[*rs1*] + *sign-extend*(*offset*)读取四个字节，写入x[*rd*]。对于RV64I，结果要进行符号位扩展。

压缩形式：**c.lwsp** rd, offset; **c.lw** rd, offset(rs1)

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| offset[11:0] | rs1 | 010 | rd | 0000011 |

lwu rd, offset(rs1) x[rd] = M[x[rs1] + sext(offset)][31:0]

无符号字加载 *(Load Word, Unsigned)*. I-type, RV64I.

从地址x[*rs1*] + *sign-extend*(*offset*)读取四个字节，零扩展后写入x[*rd*]。

31 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| offset[11:0] | rs1 | 110 | rd | 0000011 |

lui rd, immediate x[rd] = sext(immediate[31:12] << 12)

高位立即数加载 *(Load Upper Immediate)*. U-type, RV32I and RV64I.

将符号位扩展的20位立即数*immediate*左移12位，并将低12位置零，写入x[*rd*]中。

压缩形式：**c.lui** rd, imm

31 12 11 7 6 0

|  |  |  |
| --- | --- | --- |
| immediate[31:12] | rd | 0110111 |

mret ExceptionReturn(Machine)

机器模式异常返回*(Machine-mode Exception Return)*. R-type, RV32I and RV64I特权架构

从机器模式异常处理程序返回。将*pc*设置为CSRs[mepc], 将特权级设置成CSRs[mstatus].MPP, CSRs[mstatus].MIE置成CSRs[mstatus].MPIE, 并且将CSRs[mstatus].MPIE为1;并且，如果支持用户模式，则将CSR [mstatus].MPP设置为0。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0011000 | 00010 | 00000 | 000 | 00000 | 1110011 |

mul rd, rs1, rs2

乘*(Multiply)*. R-type, RV32M and RV64M.

把寄存器x[*rs2*]乘到寄存器x[*rs1*]上，乘积写入x[*rd*]。忽略算术溢出。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000001 | rs2 | rs1 | 000 | rd | 0110011 |

mulh rd, rs1, rs2

高位乘*(Multiply High)*. R-type, RV32M and RV64M.

把寄存器x[*rs2*]乘到寄存器x[*rs1*]上，都视为2的补码，将乘积的高位写入x[*rd*]。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000001 | rs2 | rs1 | 001 | rd | 0110011 |

mulhsu rd, rs1, rs2

高位有符号-无符号乘*(Multiply High Signed-Unsigned)*. R-type, RV32M and RV64M.

把寄存器x[*rs2*]乘到寄存器x[*rs1*]上，x[*rs1*]为2的补码，x[*rs2*]为无符号数，将乘积的高位写入x[*rd*]。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000001 | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 010 | rd | 0110011 |

mulhu rd, rs1, rs2

高位无符号乘*(Multiply High Unsigned)*. R-type, RV32M and RV64M.

把寄存器x[*rs2*]乘到寄存器x[*rs1*]上，x[*rs1*]、x[*rs2*]均为无符号数，将乘积的高位写入x[*rd*]。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000001 | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 011 | rd | 0110011 |

mulw rd, rs1, rs2

乘字*(Multiply Word)*. R-type, RV64M only.

把寄存器x[*rs2*]乘到寄存器x[*rs1*]上，乘积截为32位，进行有符号扩展后写入x[*rd*]。忽略算术溢出。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000001 | rs2 | rs1 | 000 | rd | 0111011 |

mv rd, rs1

移动*(Move)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

把寄存器x[*rs1*]复制到x[*rd*]中。实际被扩展为**addi** rd, rs1, 0

neg rd, rs2

取反*(Negate)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

把寄存器x[*rs2*]的二进制补码写入x[*rd*]。实际被扩展为**sub** rd, x0, rs2。

negw rd, rs2

取非字*(Negate Word)*. 伪指令(Pseudoinstruction), RV64I only.

计算寄存器x[*rs2*]对于2的补码，结果截为32位，进行符号扩展后写入x[*rd*]。实际被扩展为**subw** rd, x0, rs2。

nop

无操作*(No operation)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

将*pc*推进到下一条指令。实际被扩展为**addi** x0, x0, 0。

not rd, rs1

取反*(NOT)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

把寄存器x[*rs1*]对于1的补码（即按位取反的值）写入x[*rd*]。实际被扩展为**xori** rd, rs1, -1。

or rd, rs1, rs2

取或*(OR)*. R-type, RV32I and RV64I.

把寄存器x[*rs1*]和寄存器x[*rs2*]按位取或，结果写入x[*rd*]。

压缩形式：**c.or** rd, rs2

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000000 | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 110 | rd | 0110011 |

ori rd, rs1, immediate

立即数取或*(OR Immediate)*. R-type, RV32I and RV64I.

把寄存器x[*rs1*]和有符号扩展的立即数*immediate*按位取或，结果写入x[*rd*]。

压缩形式：**c.or** rd, rs2

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Immediate[11:0] | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 110 | rd | 0010011 |

rdcycle rd

读周期计数器*(Read Cycle Counter)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

把周期数写入x[*rd*]。实际被扩展为**csrrs** rd, cycle, x0。

rdcycleh rd

读周期计数器高位*(Read Cycle Counte High)*. 伪指令(Pseudoinstruction), RV32I only.

把周期数右移32位后写入x[*rd*]。实际被扩展为**csrrs** rd, cycleh, x0。

rdinstret rd

读已完成指令计数器*(Read Instruction-Retired Counter)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

把已完成指令数写入x[*rd*]。实际被扩展为**csrrs** rd, instret, x0。

rdinstreth rd

读已完成指令计数器高位*(Read Instruction-Retired Counter High)*. 伪指令(Pseudoinstruction), RV32I only.

把已完成指令数右移32位后写入x[*rd*]。实际被扩展为**csrrs** rd, instreth, x0。

rdtime rd

读取时间*(Read Time)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

把当前时间写入x[*rd*]，时间频率与平台相关。实际被扩展为**csrrs** rd, time, x0。

rdtimeh rd

读取时间高位*(Read Time High)*. 伪指令(Pseudoinstruction), RV32I only.

把当前时间右移32位后写入x[*rd*]，时间频率与平台相关。实际被扩展为**csrrs** rd, timeh, x0。

rem rd, rs1, rs2

求余数*(Remainder)*. R-type, RV32M and RV64M.

x[*rs1*]除以x[*rs2*]，向0舍入，都视为2的补码，余数写入x[*rd*]。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000001 | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 110 | rd | 0110011 |

remu rd, rs1, rs2

求无符号数的余数*(Remainder, Unsigned)*. R-type, RV32M and RV64M.

x[*rs1*]除以x[*rs2*]，向0舍入，都视为无符号数，余数写入x[*rd*]。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000001 | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 111 | rd | 0110011 |

remuw rd, rs1, rs2

求无符号数的余数字*(Remainder Word, Unsigned)*. R-type, RV64M only.

x[*rs1*]的低32位除以x[*rs2*]的低32位，向0舍入，都视为无符号数，将余数的有符号扩展写入x[*rd*]。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000001 | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 111 | rd | 0111011 |

remw rd, rs1, rs2

求余数字*(Remainder Word)*. R-type, RV64M only.

x[*rs1*]的低32位除以x[*rs2*]的低32位，向0舍入，都视为2的补码，将余数的有符号扩展写入x[*rd*]。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000001 | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 110 | rd | 0111011 |

ret

返回*(Return)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

从子过程返回。实际被扩展为**jalr** x0, 0(x1)。

sb rs2, offset(rs1)

存字节*(Store Byte)*. S-type, RV32I and RV64I.

将x[*rs2*]的低位字节存入内存地址x[*rs1*]+*sign-extend(offset)*。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| offset[11:5] | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 000 | offset[4:0] | 0100011 |

sc.d rd, rs2, (rs1)

条件存入双字*(Store-Conditional Doubleword)*. R-type, RV64A only.

如果内存地址x[*rs1*]上存在加载保留，将x[*rs2*]寄存器中的8字节数存入该地址。如果存入成功，向寄存器x[*rd*]中存入0，否则存入一个非0的错误码。

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 00011  31 27 26 25 24 20 19 15 14 12 11 7 6 0 | aq | rl | rs2 | rs1 | 011 | rd | 0101111 |

sc.w rd, rs2, (rs1)

条件存入字*(Store-Conditional Word)*. R-type, RV32A and RV64A.

内存地址x[*rs1*]上存在加载保留，将x[*rs2*]寄存器中的4字节数存入该地址。如果存入成功，向寄存器x[*rd*]中存入0，否则存入一个非0的错误码。

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 00011  31 27 26 25 24 20 19 15 14 12 11 7 6 0 | aq | rl | rs2 | rs1 | 010 | rd | 0101111 |

sd rs2, offset(rs1)

存双字*(Store Doubleword)*. S-type, RV64I only.

将x[*rs2*]中的8字节存入内存地址x[*rs1*]+*sign-extend(offset)*。

压缩形式：**c.sdsp** rs2, offset; **c.sd** rs2, offset(rs1)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| offset[11:5] | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 011 | offset[4:0] | 0100011 |

seqz rd, rs1

等于0则置位*(Set if Equal to Zero)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

如果x[*rs1*]等于0，向x[*rd*]写入1，否则写入0。实际被扩展为**sltiu** rd, rs1, 1。

sext.w rd, rs1

有符号字扩展*(Sign-extend Word)*. 伪指令(Pseudoinstruction), RV64I only.

读入x[*rs1*]的低32位，有符号扩展，结果写入x[*rd*]。实际被扩展为**addiw** rd, rs1, 0。

sfence.vma rs1, rs2

虚拟内存屏障*(Fence Virtual Memory)*. R-type, RV32I and RV64I特权指令。

根据后续的虚拟地址翻译对之前的页表存入进行排序。当*rs2*=0时，所有地址空间的翻译都会受到影响；否则，仅对x[*rs2*]标识的地址空间的翻译进行排序。当*rs1*=0时，对所选地址空间中的所有虚拟地址的翻译进行排序；否则，仅对其中包含虚拟地址x[*rs1*]的页面地址翻译进行排序。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0001001 | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 000 | 00000 | 1110011 |

sgtz rd, rs2

大于0则置位*(Set if Greater Than Zero)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

如果x[*rs2*]大于0，向x[*rd*]写入1，否则写入0。实际被扩展为**slt** rd, x0, rs2。

sh rs2, offset(rs1)

存半字*(Store Halfword)*. S-type, RV32I and RV64I.

将x[*rs2*]的低位2个字节存入内存地址x[*rs1*]+*sign-extend(offset)*。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| offset[11:5] | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 001 | offset[4:0] | 0100011 |

sw rs2, offset(rs1)

存字*(Store Word)*. S-type, RV32I and RV64I.

将x[*rs2*]的低位4个字节存入内存地址x[*rs1*]+*sign-extend(offset)*。

压缩形式：**c.swsp** rs2, offset; **c.sw** rs2, offset(rs1)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| offset[11:5] | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 010 | offset[4:0] | 0100011 |

sll rd, rs1, rs2

逻辑左移*(Shift Left Logical)*. R-type, RV32I and RV64I.

把寄存器x[*rs1*]左移x[*rs2*]位，空出的位置填入0，结果写入x[*rd*]。x[*rs2*]的低5位（如果是RV64I则是低6位）代表移动位数，其高位则被忽略。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000000 | rs2 | rs1 | 001 | rd | 0110011 |

slli rd, rs1, shamt

立即数逻辑左移*(Shift Left Logical Immediate)*. I-type, RV32I and RV64I.

把寄存器x[*rs1*]左移*shamt*位，空出的位置填入0，结果写入x[*rd*]。对于RV32I，仅当*shamt*[5]=0时，指令才是有效的。

压缩形式：**c.slli** rd, shamt

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 000000 | shamt | rs1 | 001 | rd  31 26 25 20 19 15 14 12 11 7 6 0 | 0010011 |

slliw rd, rs1, shamt

立即数逻辑左移字*(Shift Left Logical Word Immediate)*. I-type, RV64I only.

把寄存器x[*rs1*]左移*shamt*位，空出的位置填入0，结果截为32位，进行有符号扩展后写入x[*rd*]。仅当*shamt*[5]=0时，指令才是有效的。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 000000 | shamt | rs1 | 001 | rd  31 26 25 20 19 15 14 12 11 7 6 0 | 0011011 |

sllw rd, rs1, rs2

逻辑左移字*(Shift Left Logical Word)*. R-type, RV64I only.

把寄存器x[*rs1*]的低32位左移x[*rs2*]位，空出的位置填入0，结果进行有符号扩展后写入x[*rd*]。x[*rs2*]的低5位代表移动位数，其高位则被忽略。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000000 | rs2 | rs1 | 001 | rd  31 25 24 20 19 15 14 12 11 7 6 0 | 0111011 |

slt rd, rs1, rs2

小于则置位*(Set if Less Than)*. R-type, RV32I and RV64I.

比较x[*rs1*]和x[*rs2*]中的数，如果x[*rs1*]更小，向x[*rd*]写入1，否则写入0。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000000 | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 010 | rd | 0110011 |

slti rd, rs1, immediate

小于立即数则置位*(Set if Less Than Immediate)*. I-type, RV32I and RV64I.

比较x[*rs1*]和有符号扩展的*immediate*，如果x[*rs1*]更小，向x[*rd*]写入1，否则写入0。

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| immediate[11:0] | rs1  31 20 19 15 14 12 11 7 6 0 | 010 | rd | 0010011 |

sltiu rd, rs1, immediate

无符号小于立即数则置位*(Set if Less Than Immediate, Unsigned)*. I-type, RV32I and RV64I.

比较x[*rs1*]和有符号扩展的*immediate*，比较时视为无符号数。如果x[*rs1*]更小，向x[*rd*]写入1，否则写入0。

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| immediate[11:0] | rs1  31 20 19 15 14 12 11 7 6 0 | 011 | rd | 0010011 |

sltu rd, rs1, rs2

无符号小于则置位*(Set if Less Than, Unsigned)*. R-type, RV32I and RV64I.

比较x[*rs1*]和x[*rs2*]，比较时视为无符号数。如果x[*rs1*]更小，向x[*rd*]写入1，否则写入0。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000000 | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 011 | rd | 0110011 |

sltz rd, rs1

小于0则置位*(Set if Less Than to Zero)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

如果x[*rs1*]小于0，向x[*rd*]写入1，否则写入0。实际扩展为**slt** rd, rs1, x0。

snez rd, rs2

不等于0则置位*(Set if Not Equal to Zero)*. 伪指令(Pseudoinstruction), RV32I and RV64I.

如果x[*rs1*]不等于0，向x[*rd*]写入1，否则写入0。实际扩展为**sltu** rd, x0, rs2。

sra rd, rs1, rs2

算术右移*(Shift Right Arithmetic)*. R-type, RV32I and RV64I.

把寄存器x[*rs1*]右移x[*rs2*]位，空位用x[*rs1*]的最高位填充，结果写入x[*rd*]。x[*rs2*]的低5位（如果是RV64I则是低6位）为移动位数，高位则被忽略。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0100000 | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 101 | rd | 0110011 |

srai rd, rs1, shamt

立即数算术右移*(Shift Right Arithmetic Immediate)*. I-type, RV32I and RV64I.

把寄存器x[*rs1*]右移*shamt*位，空位用x[*rs1*]的最高位填充，结果写入x[*rd*]。对于RV32I，仅当*shamt*[5]=0时指令有效。

压缩形式：**c.srai** rd, shamt

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 010000 | shamt  31 26 25 20 19 15 14 12 11 7 6 0 | rs1 | 101 | rd | 0010011 |

sraiw rd, rs1, shamt

立即数算术右移字*(Shift Right Arithmetic Word Immediate)*. I-type, RV64I only.

把寄存器x[*rs1*]的低32位右移*shamt*位，空位用x[*rs1*][31]填充，结果进行有符号扩展后写入x[*rd*]。仅当*shamt*[5]=0时指令有效。

压缩形式：**c.srai** rd, shamt

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 010000 | shamt | rs1 | 101  31 26 25 20 19 15 14 12 11 7 6 0 | rd | 0011011 |

sraw rd, rs1, rs2

算术右移字*(Shift Right Arithmetic Word)*. R-type, RV64I only.

把寄存器x[*rs1*]的低32位右移x[*rs2*]位，空位用x[*rs1*][31]填充，结果进行有符号扩展后写入x[*rd*]。x[*rs2*]的低5位为移动位数，高位则被忽略。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0100000 | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 101 | rd | 0111011 |

sret

管理员模式例外返回*(Supervisor-mode Exception Return)*. R-type, RV32I and RV64I特权指令。

从管理员模式的例外处理程序中返回，设置*pc*为CSRs[spec]，权限模式为CSRs[sstatus].SPP，CSRs[sstatus].SIE为CSRs[sstatus].SPIE，CSRs[sstatus].SPIE为1，CSRs[sstatus].spp为0。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0001000 | 00010  31 25 24 20 19 15 14 12 11 7 6 0 | 00000 | 000 | 00000 | 1110011 |

srl rd, rs1, rs2

逻辑右移*(Shift Right Logical)*. R-type, RV32I and RV64I.

把寄存器x[*rs1*]右移x[*rs2*]位，空出的位置填入0，结果写入x[*rd*]。x[*rs2*]的低5位（如果是RV64I则是低6位）代表移动位数，其高位则被忽略。

31 25 24 20 19 15 14 12 11 7 6 0

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000000 | rs2 | rs1 | 101 | rd | 0110011 |

srli rd, rs1, shamt

立即数逻辑右移*(Shift Right Logical Immediate)*. I-type, RV32I and RV64I.

把寄存器x[*rs1*]右移*shamt*位，空出的位置填入0，结果写入x[*rd*]。对于RV32I，仅当*shamt*[5]=0时，指令才是有效的。

压缩形式：**c.srli** rd, shamt

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 000000 | shamt | rs1 | 101 | rd  31 26 25 20 19 15 14 12 11 7 6 0 | 0010011 |

srliw rd, rs1, shamt

立即数逻辑右移字*(Shift Right Logical Word Immediate)*. I-type, RV64I only.

把寄存器x[*rs1*]右移*shamt*位，空出的位置填入0，结果截为32位，进行有符号扩展后写入x[*rd*]。仅当*shamt*[5]=0时，指令才是有效的。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 000000 | shamt | rs1 | 101 | rd  31 26 25 20 19 15 14 12 11 7 6 0 | 0011011 |

srlw rd, rs1, rs2

逻辑右移字*(Shift Right Logical Word)*. R-type, RV64I only.

把寄存器x[*rs1*]的低32位右移x[*rs2*]位，空出的位置填入0，结果进行有符号扩展后写入x[*rd*]。x[*rs2*]的低5位代表移动位数，其高位则被忽略。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000000 | rs2 | rs1 | 101 | rd  31 25 24 20 19 15 14 12 11 7 6 0 | 0111011 |

sub rd, rs1, rs2

减*(Substract)*. R-type, RV32I and RV64I.

x[*rs1*]减去x[*rs2*]，结果写入x[*rd*]。忽略算术溢出。

压缩形式：**c.sub** rd, rs2

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0100000 | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 000 | rd | 0110011 |

subw rd, rs1, rs2

减去字*(Substract Word)*. R-type, RV64I only.

x[*rs1*]减去x[*rs2*]，结果截为32位，有符号扩展后写入x[*rd*]。忽略算术溢出。

压缩形式：**c.subw** rd, rs2

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0100000 | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 000 | rd | 0111011 |

tail symbol

尾调用*(Tail call)*. 伪指令(Pseudoinstuction), RV32I and RV64I.

设置*pc*为*symbol*，同时覆写x[6]。实际扩展为**auipc** x6, offsetHi和**jalr** x0, offsetLo(x6)。

wfi

等待中断*(Wait for Interrupt)*. R-type, RV32I and RV64I特权指令。

如果没有待处理的中断，则使处理器处于空闲状态。

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0001000 | 00101  31 25 24 20 19 15 14 12 11 7 6 0 | 00000 | 000 | 00000 | 1110011 |

xor rd, rs1, rs2

异或*(Exclusive-OR)*. R-type, RV32I and RV64I.

x[*rs1*]和x[*rs2*]按位异或，结果写入x[*rd*]。

压缩形式：**c.xor** rd, rs2

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0000000 | rs2  31 25 24 20 19 15 14 12 11 7 6 0 | rs1 | 100 | rd | 0110011 |

xori rd, rs1, immediate

立即数异或*(Exclusive-OR Immediate)*. I-type, RV32I and RV64I.

x[*rs1*]和有符号扩展的*immediate*按位异或，结果写入x[*rd*]。

压缩形式：**c.xor** rd, rs2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| immediate[11:0] | rs1  31 20 19 15 14 12 11 7 6 0 | 100 | rd | 0010011 |