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

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

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.addiw** rd, imm; **c.addi** rd, im; **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

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

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)

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 | 000 | rd | 0101111 |

amoadd.w rd, rs2, (rs1)

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)

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)

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)

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)

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)

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)

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)

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)

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)

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)

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)

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)

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)

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)

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)

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)

原子字异或 *(Atomic Memory Operation:X 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*]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

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

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.andiw** rd, imm

31 20 19 15 14 12 11 7 6 0

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

auipc rd, immediate

*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 | 0010011 |

beq rs1, rs2, 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

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

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 |

bge rs1, rs2, 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

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

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

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

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

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

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

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

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

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

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

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

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

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

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 | rs2 | 01 |

c.addi16sp 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[4j6j8:7j5] | 01 |

c.addi4spn rd’, 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

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’

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’

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

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

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

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

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’)

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)

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’)

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)

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[4:3|8:6] | 10 |

c.fsd rs2’, uimm(rs1’)

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)

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’)

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)

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

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

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

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

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’)

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)

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

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

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’)

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)

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

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’

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’)

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)

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

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

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

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’

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’

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’)

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)

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’

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

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

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

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]

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

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]

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

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]

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]

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]

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 |

csrc csr, 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.

csrci csr, zimm[4:0]

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

写控制状态寄存器 *(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.

csrwi csr, zimm[4:0]

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

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

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

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

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

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

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

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

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

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.