| 31 30 29 28 27 26 25 | 24 23 22 21 20 | 19 18 17 16 15 | 14 13 12 | 11 10 9 8 7 | 6 5 4 3 2 1 0 | |
|---|---|---|---|---|---|---|
| funct7 | rs2 | rs1 | funct3 | rd | opcode | R-type |
| imm[11:0] | | rs1 | funct3 | rd | opcode | I-type |
| imm[11:5] | rs2 | rs1 | funct3 | imm[4:0] | opcode | S-type |
| imm[12\|10:5] | rs2 | rs1 | funct3 | rd | opcode | B-type |
| imm[31:12] | | | | rd | opcode | U-type |
| imm[20\|10:1\|11\|19:12] | | | | rd | opcode | J-type |

## **Zbb**: “Basic bit-manipulation” Extension

| 31 25 | 24 20 | 19 15 | 14 12 | 11 7 | 6 0 | |
|---|---|---|---|---|---|---|
| 0 1 0 0 0 0 0 | rs2 | rs1 | 1 1 1 | rd | 0 1 1 0 0 1 1 | ANDN |
| 0 1 0 0 0 0 0 | rs2 | rs1 | 1 1 0 | rd | 0 1 1 0 0 1 1 | ORN |
| 0 1 0 0 0 0 0 | rs2 | rs1 | 1 0 0 | rd | 0 1 1 0 0 1 1 | XNOR |
| 0 1 1 0 0 0 0 | 0 0 0 0 0 | rs1 | 0 0 1 | rd | 0 0 1 0 0 1 1 | CLZ |
| 0 1 1 0 0 0 0 | 0 0 0 0 1 | rs1 | 0 0 1 | rd | 0 0 1 0 0 1 1 | CTZ |
| 0 1 1 0 0 0 0 | 0 0 0 1 0 | rs1 | 0 0 1 | rd | 0 0 1 0 0 1 1 | CPOP |
| 0 0 0 0 1 0 1 | rs2 | rs1 | 1 1 0 | rd | 0 1 1 0 0 1 1 | MAX |
| 0 0 0 0 1 0 1 | rs2 | rs1 | 1 1 1 | rd | 0 1 1 0 0 1 1 | MAXU |
| 0 0 0 0 1 0 1 | rs2 | rs1 | 1 0 0 | rd | 0 1 1 0 0 1 1 | MIN |
| 0 0 0 0 1 0 1 | rs2 | rs1 | 1 0 1 | rd | 0 1 1 0 0 1 1 | MINU |
| 0 1 1 0 0 0 0 | 0 0 1 0 0 | rs1 | 0 0 1 | rd | 0 0 1 0 0 1 1 | SEXT.B |
| 0 1 1 0 0 0 0 | 0 0 1 0 1 | rs1 | 0 0 1 | rd | 0 0 1 0 0 1 1 | SEXT.H |
| 0 0 0 0 1 0 0 | 0 0 0 0 0 | rs1 | 1 0 0 | rd | 0 1 1 0 0 1 1 | ZEXT.H |
| 0 1 1 0 0 0 0 | rs2 | rs1 | 0 0 1 | rd | 0 1 1 0 0 1 1 | ROL |
| 0 1 1 0 0 0 0 | rs2 | rs1 | 1 0 1 | rd | 0 1 1 0 0 1 1 | ROR |
| 0 1 1 0 0 0 0 | shamt | rs1 | 1 0 1 | rd | 0 0 1 0 0 1 1 | RORI |
| 0 0 1 0 1 0 0 | 0 0 1 1 1 | rs1 | 1 0 1 | rd | 0 0 1 0 0 1 1 | ORC.B |
| 0 1 1 0 1 0 0 | 1 1 0 0 0 | rs1 | 1 0 1 | rd | 0 0 1 0 0 1 1 | REV8 |

| 31 30 29 28 27 26 25 | 24 23 22 21 20 | 19 18 17 16 15 | 14 13 12 | 11 10 9 8 7 | 6 5 4 3 2 1 0 | |
|---|---|---|---|---|---|---|
| funct7 | rs2 | rs1 | funct3 | rd | opcode | R-type |
| imm[11:0] | | rs1 | funct3 | rd | opcode | I-type |
| imm[11:5] | rs2 | rs1 | funct3 | imm[4:0] | opcode | S-type |
| imm[12\|10:5] | rs2 | rs1 | funct3 | rd | opcode | B-type |
| imm[31:12] | | | | rd | opcode | U-type |
| imm[20\|10:1\|11\|19:12] | | | | rd | opcode | J-type |

## **Zri**: “Load/Store indirect with Index” Extension

| 31 25 | 24 20 | 19 15 | 14 12 | 11 7 | 6 0 | |
|---|---|---|---|---|---|---|
| 0 0 0 0 0 0 0 | rs2 | rs1 | 1 1 1 | rd | 0 0 0 0 0 1 1 | LB.R |
| 0 0 0 0 0 0 1 | rs2 | rs1 | 1 1 1 | rd | 0 0 0 0 0 1 1 | LH.R |
| 0 0 0 0 0 1 0 | rs2 | rs1 | 1 1 1 | rd | 0 0 0 0 0 1 1 | LW.R |
| 1 0 0 0 0 0 0 | rs2 | rs1 | 1 1 1 | rd | 0 0 0 0 0 1 1 | LBU.R |
| 1 0 0 0 0 0 1 | rs2 | rs1 | 1 1 1 | rd | 0 0 0 0 0 1 1 | LHU.R |
| 0 0 0 0 0 0 0 | rs3 | rs1 | 1 1 1 | rs2 | 0 1 0 0 0 1 1 | SB.R |
| 0 0 0 0 0 0 1 | rs3 | rs1 | 1 1 1 | rs2 | 0 1 0 0 0 1 1 | SH.R |
| 0 0 0 0 0 1 0 | rs3 | rs1 | 1 1 1 | rs2 | 0 1 0 0 0 1 1 | SW.R |

```
lb    rd, rs2(rs1)
lh    rd, rs2(rs1)
lw    rd, rs2(rs1)
lbu   rd, rs2(rs1)
lhu   rd, rs2(rs1)
sb    rs2, rs3(rs1)
sh    rs2, rs3(rs1)
sw    rs2, rs3(rs1)
```

| 31 30 29 28 27 26 25 | 24 23 22 21 20 | 19 18 17 16 15 | 14 13 12 | 11 10 9 8 7 | 6 5 4 3 2 1 0 | |
|---|---|---|---|---|---|---|
| funct7 | rs2 | rs1 | funct3 | rd | opcode | R-type |
| imm[11:0] | | rs1 | funct3 | rd | opcode | I-type |
| imm[11:5] | rs2 | rs1 | funct3 | imm[4:0] | opcode | S-type |
| imm[12\|10:5] | rs2 | rs1 | funct3 | rd | opcode | B-type |
| imm[31:12] | | | | rd | opcode | U-type |
| imm[20\|10:1\|11\|19:12] | | | | rd | opcode | J-type |

## **Zor**: "Objective RISC" Extension

Unprivileged:

| 31 25 | 24 20 | 19 15 | 14 12 | 11 7 | 6 0 | | |
|---|---|---|---|---|---|---|---|
| 0 0 0 0 0 0 0 | rs2 | rs1 | 0 0 0 | rs3 | 0 0 0 1 0 1 1 | SP.R | R |
| 0 0 0 0 0 0 1 | rs2 | rs1 | 0 0 0 | rd | 0 0 0 1 0 1 1 | LP.R | R |
| 0 0 0 0 0 1 0 | index[4:0] | frame | 0 0 0 | rs1 | 0 0 0 1 0 1 1 | SV | R |
| 0 0 0 0 0 1 1 | index[4:0] | frame | 0 0 0 | rd | 0 0 0 1 0 1 1 | RST | R |
| 0 0 0 0 1 0 0 | zero | rs1 | 0 0 0 | rd | 0 0 0 1 0 1 1 | QDTB | R |
| 0 0 0 0 1 0 1 | zero | rs1 | 0 0 0 | rd | 0 0 0 1 0 1 1 | QDTH | R |
| 0 0 0 0 1 1 0 | zero | rs1 | 0 0 0 | rd | 0 0 0 1 0 1 1 | QDTW | R |
| 0 0 0 0 1 1 1 | zero | rs1 | 0 0 0 | rd | 0 0 0 1 0 1 1 | QDTD | R |
| 0 0 0 1 0 0 0 | zero | rs1 | 0 0 0 | rd | 0 0 0 1 0 1 1 | QPI | R |
| 0 0 0 1 0 0 1 | zero | zero | 0 0 0 | rd | 0 0 0 1 0 1 1 | GCP | R |
| 0 0 0 1 1 0 0 | zero | frame | 0 0 0 | frame | 0 0 0 1 0 1 1 | POP | R |
| 0 0 1 0 0 0 1 | zero | zero | 0 0 0 | zero | 0 0 0 1 0 1 1 | RTLIB | R |
| 0 0 1 0 0 1 0 | zero | zero | 0 0 0 | zero | 0 0 0 1 0 1 1 | CPFC | R |
| 0 0 1 0 0 1 1 | zero | zero | 0 0 0 | zero | 0 0 0 1 0 1 1 | CHECK | R |
| imm[11:5] | rs2 | rs1 | 0 0 1 | imm[4:0] | 0 0 0 1 0 1 1 | SP | S |
| imm[11:0] | | rs1 | 0 1 0 | rd | 0 0 0 1 0 1 1 | LP | I |
| imm[11:0] | | rs1 | 0 1 1 | ra | 0 0 0 1 0 1 1 | JLIB | I |
| 0 0 0 0 0 0 0 | rs2 | rs1 | 1 0 0 | rd | 0 0 0 1 0 1 1 | ALC | R |
| pi[11:0] | | rs1 | 1 0 1 | rd | 0 0 0 1 0 1 1 | ALCI.P | I |
| dt[11:0] | | rs1 | 1 1 0 | rd | 0 0 0 1 0 1 1 | ALCI.D | I |
| dt[6:0] | 0 0 0 0 0 | rd | 1 1 1 | pi[4:0] | 0 0 0 1 0 1 1 | ALCI | S |
| dt[6:0] | 0 0 0 1 0 | frame | 1 1 1 | pi[4:0] | 0 0 0 1 0 1 1 | PUSHG | S |
| dt[6:0] | 0 0 0 1 1 | frame | 1 1 1 | pi[4:0] | 0 0 0 1 0 1 1 | PUSH | S |

Machine Mode:

| 31 26 | 25 24 | 20 19 | 15 14 | 12 11 | 7 6 | 0 | | |
|---|---|---|---|---|---|---|---|---|
| 1 1 1 1 1 1 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 | rd | 1 1 1 0 0 1 1 | ALCB | R |
| 1 1 1 1 1 1 1 | rs2 | rs1 | 0 0 0 | rd | 1 1 1 0 0 1 1 | CIOP | R |
| 1 1 1 1 1 1 0 | 1 0 0 0 0 | rs1 | 0 0 0 | rd | 1 1 1 0 0 1 1 | CCP | R |
| 1 1 1 1 1 1 0 | 1 0 0 0 1 | rs1 | 0 0 0 | rd | 1 1 1 0 0 1 1 | RPR | R |
| 1 1 1 1 1 1 0 | 1 0 1 0 0 | rs1 | 0 0 0 | rd | 1 1 1 0 0 1 1 | QPIR | R |
| 1 1 1 1 1 1 0 | 1 0 1 0 1 | rs1 | 0 0 0 | rd | 1 1 1 0 0 1 1 | QDTR | R |
| 1 1 1 1 1 1 0 | 1 0 1 1 0 | rs1 | 0 0 0 | rd | 1 1 1 0 0 1 1 | QPTR | R |
| 1 1 1 1 1 1 0 | 0 0 0 0 0 | 0 0 0 1 0 | 0 0 0 | rd | 1 1 1 0 0 1 1 | SEAL | R |
| 1 1 1 1 1 1 0 | 0 0 0 0 0 | 0 0 0 1 1 | 0 0 0 | rd | 1 1 1 0 0 1 1 | UNSL | R |

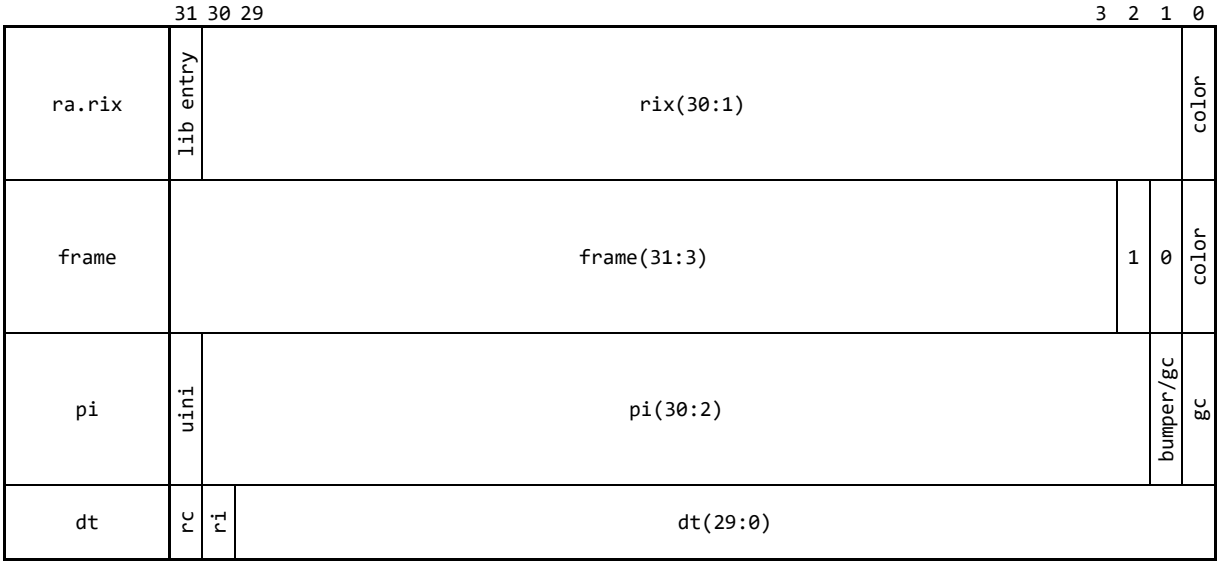
Misc:

| reg | alias | reg | alias |
|---|---|---|---|
| x0 | zero | x16 | a6 |
| x1 | ra ~~rix~~ | x17 | a7 |
| x2 | frame | x18 | s2 |
| x3 | ~~rcd/~~root/core | x19 | s3 |
| x4 | ctxt | x20 | s4 |
| x5 | t0 | x21 | s5 |
| x6 | t1 | x22 | s6 |
| x7 | t2 | x23 | s7 |
| x8 | s0 | x24 | s8 |
| x9 | s1 | x25 | s9 |
| x10 | a0 | x26 | s10/bm |
| x11 | a1 | x27 | cnst |
| x12 | a2 | x28 | t3 |
| x13 | a3 | x29 | t4 |
| x14 | a4 | x30 | t5 |
| x15 | a5 | x31 | t6 |

| pseudo-instruction | implemented as |
|---|---|
| lcp rd, imm(rs1) | lp rd, imm(rs1)<br>sp x0, imm(rs1) |
| lcp.r rd, imm(rs1) | lp.r rd, rs2(rs1)<br>sp.r x0, rs2(rs1) |
| scp rs2, imm(rs1) | sp rs2, imm(rs1)<br>addi rs2, x0,0 |
| scp.r rs2, rs3(rs1) | sp.r rs2, rs3(rs1)<br>addi rs2, x0,0 |
| pusht pi,dt | alci frame, pi,dt |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

Implementation:

| Instruction | rdst | rdat | rptr | raux | imm |
|---|---|---|---|---|---|
| sb/h/w | zero | ra.rix | rs1 | rs2 | imm |
| lb/bu/h/hu/w | rd | ra.rix | rs1 | ra.rcd | imm |
| sp | zero | ra.rix | rs1 | rs2 | imm |
| lp | rd | ra.rix | rs1 | ra.rcd | imm |
| sb/h/w.r | zero | rs3 | rs1 (≠ frame) | rs2 | --- |
| lb/bu/h/hu/w.r | rd | rs2 | rs1 (≠ frame) | --- | --- |
| sp.r | zero | rs3 | rs1 (≠ frame) | rs2 | --- |
| lp.r | rd | rs2 | rs1 (≠ frame) | --- | --- |
| sv | zero | ra.rix | frame | rs1 | index |
| rst | rd | ra.rix | frame | bm | index |
| qdtx | | | | | |
| qpi | | | | | |
| gcp | | | | | |
| pop | frame | ra.rix | frame | --- | --- |
| jlib | ra | ra.rix | rs1 | frame | imm |
| jal | rd | --- | ra | frame | imm |
| jr | rd | rs1 | ra | frame | imm |
| rtlib | ra | ra.rix | ra | frame | --- |
| alc | rd (≠ frame) | rs1 | alc_addr | rs2 | --- |
| alci.p | rd (≠ frame) | rs1 | alc_addr | --- | pi |
| alci.d | rd (≠ frame) | rs1 | alc_addr | --- | dt |
| alci | rd | ra.rix | alc_addr | frame | pi & dt |
| pushg | rd | ra.rix | --- | frame | pi & dt |
| push | rd | ra.rix | --- | frame | pi & dt |
| alcb | | | | | |
| ciop | | | | | |
| rpr | | | | | |
| qpir | | | | | |
| qdtr | | | | | |
| qptr | | | | | |
| seal | | | | | |
| unsl | | | | | |




| instruction | condition | action |
|---|---|---|
| jlib | ra.rix(color) != frame(color)<br>target ptr != ra.rcd | set ra.rix(lib entry), toggle rix(color) |
| jal ra, ... or jr ra, ... | ra.rix(color) != frame(color) | clear ra.rix(lib entry), toggle rix(color) |
| pushx | ra.rix(color) = frame(color) | toggle frame(color) |
| pop | ra.rix(color) != frame(color) | toggle frame(color) |
| jr ..., 0(ra) | ra.rix(color) = frame(color) | toggle ra.rix(color)<br>if ra.rix(lib entry) = 1 do cross code-object return<br>else stay in this code-object |