|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 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 |  | pseudo-instruction | implemented as |
| x0 | zero | x16 | a6 |  | lcp rd, imm(rs1) | lp rd, imm(rs1) |
| x1 | ra ~~rix~~ | x17 | a7 |  |  | sp x0, imm(rs1) |
| x2 | frame | x18 | s2 |  | lcp.r rd, imm(rs1) | lp.r rd, rs2(rs1) |
| x3 | ~~rcd/~~root/core | x19 | s3 |  |  | sp.r x0, rs2(rs1) |
| x4 | ctxt | x20 | s4 |  | scp rs2, imm(rs1) | sp rs2, imm(rs1) |
| x5 | t0 | x21 | s5 |  |  | addi rs2, x0,0 |
| x6 | t1 | x22 | s6 |  | scp.r rs2, rs3(rs1) | sp.r rs2, rs3(rs1) |
| x7 | t2 | x23 | s7 |  |  | addi rs2, x0,0 |
| x8 | s0 | x24 | s8 |  | pusht pi,dt | alci frame, pi,dt |
| 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 |  |  |  |

Implementation:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Instruction** | **rdst** | **rdat** | **rptr** | **raux** | **imm** |
| sb/h/w | zero | ra.rix | rs1 | rs2 | imm |
| lb/bu/h/hu/w | rd | --- | rs1 | ra | imm |
| sp | zero | ra.rix | rs1 | rs2 | imm |
| lp | rd | --- | rs1 | ra | 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 | frame | rs1 | ra | imm |
| jal | rd | frame | --- | ra | imm |
| jr | rd | frame | rs1 | ra | imm |
| rtlib | ra | ra.rix | ra | frame | --- |
| alc | rd (≠ frame) | rs1 | alc\_params | rs2 | --- |
| alci.p | rd (≠ frame) | rs1 | alc\_params | --- | pi |
| alci.d | rd (≠ frame) | rs1 | alc\_params | --- | dt |
| alci | rd | ra.rix | alc\_params | frame | pi & dt |
| pushg | rd | ra.rix | alc\_params | frame | pi & dt |
| push | rd | ra.rix | alc\_params | frame | pi & dt |
| alcb |  |  |  |  |  |
| ciop | rd | rs1 | --- | rs2 | --- |
| rpr |  |  |  |  |  |
| qpir |  |  |  |  |  |
| qdtr |  |  |  |  |  |
| qptr |  |  |  |  |  |
| seal |  |  |  |  |  |
| unsl |  |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 31 | 30 | 29 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 3 | 2 | 1 | 0 |
| ra.rix | lib entry | rix(30:1) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | color |
| frame | frame(31:3) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 0 | color |
| pi | uini | pi(30:2) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | bumper/gc | gc |
| dt | rc | ri | dt(29:0) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

|  |  |  |
| --- | --- | --- |
| instruction | condition | action |
| jlib | ra.rix(color) != frame(color) 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) if ra.rix(lib entry) = 1 do cross code-object return else stay in this code-object |

**OBJECTS**

Ordinary

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 31 | 30 | 29 |  | 2 | 1 | 0 |
| gc | | size(29:2) | | | 0 | 0 |
|  | | | | | | |
|  | | | | | | |
| ... | | | | | | |
|  | | | | | | |
|  | | | | | | |

Frame

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 31 | 30 | 29 |  | 3 | 2 | 1 | 0 |
| gc | | c | size(28:4) | f | r | 1 | 0 |
| ra-ptr? | | | | | | | |
| fp-ix? | | | | | | | |
| fp-eop! | | | | | | | |
| ra-ix! | | | | | | | |
| fp-ptr! | | | | | | | |
|  | | | | | | | |
| ... | | | | | | | |
|  | | | | | | | |

Data only

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 31 | 30 | 29 |  | 2 | 1 | 0 |
| gc | | size(29:2) | | | 0 | 1 |
|  | | | | | | |
|  | | | | | | |
| ... | | | | | | |
|  | | | | | | |
|  | | | | | | |

Code

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 31 |  | 2 | 1 | 0 |
| eoc(30:1) | | | 1 | 1 |
| eop(30:1) | | | 1 | 1 |
|  | | | | |
| ... | | | | |
|  | | | | |

Immediate (Primitive)

|  |  |  |
| --- | --- | --- |
| 31 |  | 0 |
| integer | | |

Immediate (Pointer)

|  |  |  |
| --- | --- | --- |
| 31 |  | 0 |
| ptr | | |
| ix | | |
| attr | | |

**POINTERS & DATA  
(in memory)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 31 |  | 1 | 0 |
| immediate (prim) pointer: | ptr(31:2) | | 0 | 1 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | 31 |  | 3 | 2 | 1 | 0 |
| ord./code/d.o.-ptr: | ptr(31:4) | | 0 | 0 | 1 | 1 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | 31 |  | 3 | 2 | 1 | 0 |
| immediate (ptr) pointer: pc pointer: | ptr(31:4) | | 0 | 1 | 1 | 1 |

(*immediate (ptr) pointers* shall never be present in the register-file. pc pointers shall never be stored to memory, except in the hidden ra-ptr spot of stack-frames)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 31 |  | | 4 | 3 | 2 | 1 | 0 |
| io pointer: | dev | | size | g | 1 | 1 | 1 | 1 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 32 | 31 | 25 | 24 | | 17 | 16 | | 9 | 8 | | 1 | 0 |
| Small Data (w): | 31 | int(30:0) | | | | | | | | | | | 0 |
| Small Data (h): | 15 | h1(14:0) | | | | | | h0(15:0) | | | | | 0 |
| Small Data (b): | 7 | b3 | | | b2 | | | b1 | | | b0 | | 0 |

Allocate immediate primitive if:

* sw and rs(30) ≠ rs(31)
* sh at h1 and rs(14) ≠ rs(15)
* sb at b3 and (rs(7) = 1 or rs < 0)

**REGISTER FILE & PIPELINE**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | T |  | 31 |  | 0 |  |  |  |  |
| **data** | 0 |  | value(31:0) | | |  | alc\_addr |  | alc\_lim |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | T |  | 31 |  | 4 | 3 | 2 | 1 | 0 |  | 31 |  | 0 |  | 31 | 30 | 29 |  | 2 | 1 | 0 |
| **ordinary pointer** | 1 |  | ptr(31:4) | | | 0 | 0 | 0 | 0 |  | index(31:0) | | |  | 0 | 0 | size(29:2) | | | 0 | 0 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | T |  | 31 |  | 4 | 3 | 2 | 1 | 0 |  | 31 |  | 0 |  | 31 | 30 |  |  |  | 1 | 0 |
| **code pointer** | 1 |  | ptr(31:4) | | | 0 | 1 | 0 | 0 |  | eop(31:0) | | |  | 0 | eoc(30:1) | | | | | 0 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | T |  | 31 |  | 4 | 3 | 2 | 1 | 0 |  | 31 |  | 0 |  | 31 | 30 |  |  |  | 1 | 0 |
| **pc pointer** | 1 |  | ptr(31:4) | | | 1 | 0 | 0 | 0 |  | index(31:0) | | |  | 0 | eoc(30:1) | | | | | 0 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | T |  | 31 |  | 4 | 3 | 2 | 1 | 0 |  | 31 |  | 0 |  | 31 | 30 | 29 |  | 2 | 1 | 0 |
| **sp-type** | 1 |  | ptr(31:4) | | | 0 | 0 | 0 | 1 |  | eop(31:0) | | |  | 0 | 0 | size(29:2) | | | 0 | 0 |

contents of sp (x2) may be moved to another register, but stack-frames may only be allocated using sp and the public area may only be increased by operations on sp.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | T |  | 31 |  | 4 | 3 | 2 | 1 | 0 |  | 31 |  | 0 |  | 31 |  |  |  |  |  | 0 |
| **fp-type** | 1 |  | ptr(31:4) | | | 0 | 0 | 1 | 0 |  | index(31:0) | | |  | eop(31:0) | | | | | | |

contents of fp (x8) may be moved to another register, but the public area of the past stack frame may only be accessed using fp.  
highest valid address for memory access using fp-types: fp(eop)  
lowest valid address for memory access using fp-types: sp

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | T |  | 31 |  | 4 | 3 | 2 | 1 | 0 |  | 31 |  | 0 |  | 31 | 30 | 29 |  | 2 | 1 | 0 |
| **io pointer** | 1 |  | dev(27:0) | | | 1 | 1 | 0 | 0 |  | index(31:0) | | |  | g | size(29:2) | | | | 0 | 0 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Instruction** | **rdst** | **rdat** | **rptr** | **raux** | **imm** |
| lui | rd | --- | --- | --- | imm |
| auipc | rd | --- | --- | --- | imm |
| jal | rd | --- | --- | --- | imm |
| jalr | rd | --- | rs1 | --- | imm |
| bcc | --- | rs1 | --- | rs2 | imm |
| lb/bu/h/hu/w | rd | --- | rs1 | ra | imm |
| sb/h/w | (sp) | ra.rix | rs1 | rs2 | imm |
| addi | rd | ra.rix | sp | rs1 | imm |
| arithi | rd | rs1 | --- | --- | imm |
| arith | rd | rs2 | --- | rs1 | --- |
| alc | rd | rs1 | alc\_params | --- | --- |
| alci | rd | --- | alc\_params | --- | imm |
| alc.d | rd | rs1 | alc\_params | --- | --- |
| alci.d | rd | --- | alc\_params | --- | imm |
| qsz | rd | --- | rs1 | --- | --- |
|  |  |  |  |  |  |

**addi**

|  |  |
| --- | --- |
| dc | if rs1 = sp then set me\_mode = alloc else set alu\_mode = add |
| ex | if color(sp) ≠ color(ra) and rs1 = sp then set alloc\_frame\_header = true and generate frame header struct  else alloc\_frame\_header = false |
| me | if me\_mode = alloc then init stack-frame  if alloc\_frame\_header then store frame header |
| at | --- |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | +3 | +2 | +1 | +0 |  |
|  | **π** | | | | 0 |
|  | **δ** | | | | 4 |
|  |  | | | | 8 |
|  |  | | | |  |
|  |  | | | |  |
|  |  | | | |  |
|  |  | | | | π\*4+8 |
|  |  |  |  |  | π\*4+12 |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  | π\*4+8+δ |

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
|  | **ρ** | | 0 |
|  | **ξ** | | 4 |
|  |  |  | 8 |
|  |  | |  |
|  |  | | ρ+8 |
|  |  |  | ρ+12 |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  | ξ |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | TAG | WERT | | ATTRIBUT 1 | ATTRIBUT 2 |
| **Daten** | **0** | **Data** | | **null** | **null** |
| **Datenobjektzeiger** | **1** | **Pointer** | **000** | **Größe Zeigerbereich (π)** | **Größe Datenbereich (δ)** |
| **Code-Objektzeiger** | **1** | **Pointer** | **010** | **Ende öffentlicher Bereich (ρ)** | **Ende Code-Objekt (ξ)** |
| **PC-Zeiger** | **1** | **Pointer** | **011** | **Index  (χ)** | **Ende Code-Objekt (ξ)** |
|  |  |  | |  |  |
|  |  |  | |  |  |
|  |  |  | |  |  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | |  |  |
| **s0** | **0** | **Data** | | **null** | **null** |
| **s1** | **1** | **Pointer** | **000** | **π** | **δ** |
| **a0** | **1** | **Pointer** | **010** | **ρ** | **ξ** |
| **a1** | **1** | **Pointer** | **011** | **χ** | **ξ** |
| **a2** | **0** | **Data** | | **null** | **null** |
| **a3** | **0** | **Data** | | **null** | **null** |
| **a4** | **1** | **Pointer** | **000** | **π** | **δ** |