

# Frost64 Utility CPU

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## 2 Registers, Main Widths, etc.

- The main width of the processor is 32-bit, contrary to what the name of the processor suggests. Addresses are 32-bit.
- General Purpose Registers (32-bit) There are sixteen general-purpose registers:
  - zero: index 0x0, always zero
  - u0: index 0x1
  - u1: index 0x2
  - u2: index 0x3
  - u3: index 0x4
  - u4: index 0x5
  - u5: index 0x6
  - u6: index 0x7
  - u7: index 0x8
  - u8: index 0x9
  - u9: index 0xa
  - u10: index 0xb
  - u11: index 0xc
  - lr: index 0xd, link register
  - fp: index 0xe, frame pointer
  - sp: index 0xf, stack pointer

There are a few special-purpose registers:

- pc: index 0x0, program counter
  - \* Note that writes into this register forcibly have the LSB set to 0b0.
- ira: index 0x1, interrupt return address
- ida: index 0x2, interrupt destination address
- inp: index 0x3, interrupt pin (which interrupt pin was asserted)
- ie: index 0x4, interrupt enable

## 3 Instructions

### 3.1 Group 0 Instructions

- Encoding: 0ooo aaaa iiii iiii
  - o: opcode
  - a: general-purpose register rA

- i: 8-bit unsigned immediate `imm8` or 8-bit signed immediate `simm8`

- Instruction List:

1. `cpyi rA, imm8`
  - This instruction sets `rA` to the immediate value.
2. `cpyi1 rA, imm8`
  - This instruction sets byte 1 of `rA` to the immediate value.
3. `cpyi2 rA, imm8`
  - This instruction sets byte 2 of `rA` to the immediate value.
4. `cpyi3 rA, imm8`
  - This instruction sets byte 3 (msb) of `rA` to the immediate value.
5. `addsi rA, simm8`
  - This instruction writes `rA + to_s32(simm8)` into `rA`.
6. `addsi rA, pc, simm8`
  - This instruction writes `pc + to_s32(imm8)` into `rA`
7. `bz rA, simm8`
  - Relative branch if `rA` is *zero*.
  - Note that the branch offset is treated as `simm8 << 1`.
8. `bnz rA, simm8`
  - Relative branch if `rA` is *non-zero*.
  - Note that the branch offset is treated as `simm8 << 1`.

### 3.2 Group 1 Instructions

- Encoding: `1000 aaaa oooi iiii`
  - a: general-purpose register `rA` or special-purpose register `sA`
  - o: opcode
  - i: 5-bit unsigned immediate `imm5` or 5-bit signed immediate `simm5`

- Instruction List:

1. `sltui rA, imm5`
2. `sltsi rA, simm5`
3. `xorsi rA, simm5`
4. `xorsi sA, simm5`
5. `lsli rA, imm5`
6. `lsri rA, imm5`
7. `asri rA, imm5`
8. *Reserved for future expansion.*

### 3.3 Group 2 Instructions

- Encoding: 1001 aaaa bbbb oooo

- a: general-purpose register rA
- b: general-purpose register rB
- o: opcode

- Instruction List:

1. add rA, rB
2. sub rA, rB
3. sltu rA, rB
4. slts rA, rB
5. and rA, rB
6. orr rA, rB
7. xor rA, rB
8. lsl rA, rB
9. lsr rA, rB
10. asr rA, rB
11. mul rA, rB
12. udiv rA, rB
13. sdiv rA, rB
14. *add rA, rB, fp*
15. *add rA, rB, sp*
16. *add rA, rB, pc*

### 3.4 Group 3 Instructions

- Encoding: 1010 aaaa bbbb oooo

- a: general-purpose register rA or special-purpose register sA
- b: general-purpose register rB or special-purpose register sB
- o: opcode

- Instruction List:

1. ldb rA, [rB]
2. ldsb rA, [rB]
3. stb rA, [rB]
4. ldh rA, [rB]

5. `ldsh rA, [rB]`
6. `sth rA, [rB]`
7. `ldr sA, [rB, sp]`
8. `str sA, [rB, sp]`
9. `cpy rA, rB`
  - Copy `rB` to `rA`
10. `cpy rA, sB`
  - Copy `sB` to `rA`
11. `cpy sA, rB`
  - Copy `rB` to `sA`
12. `reti`
  - Return from an interrupt, enabling interrupts (by setting the low bit of `ie` to `0b1`) and jumping to the program counter value at `ira`.
13. `zeb rA, rB`
  - Zero extend the low 8 bits of `rB` and write the result into `rA`.
14. `zeh rA, rB`
  - Zero extend the low 16 bits of `rB` and write the result into `rA`.
15. `seb rA, rB`
  - Sign extend the low 8 bits of `rB` and write the result into `rA`.
16. `seh rA, rB`
  - Sign extend the low 16 bits of `rB` and write the result into `rA`.

### 3.5 Group 4 Instructions

- Encoding: `1011 iiii iiii iiii`
  - `i`: 12-bit signed immediate, `simm12`
- Instruction List:
  1. `bl simm12`
    - This instruction sets `lr` to `pc + 2` and jumps to the address `pc + (to_s32(simm12) << 1)`.

### 3.6 Group 5 Instructions

- Encoding: `1100 aaaa bbbb cccc`
  - `a`: general-purpose register `rA`
  - `b`: general-purpose register `rB`
  - `c`: general-purpose register `rC`
- Instruction List:
  1. `ldr rA, [rB, rC]`

### 3.7 Group 6 Instructions

- Encoding: 1101 aaaa bbbb cccc
  - a: general-purpose register rA
  - b: general-purpose register rB
  - c: general-purpose register rC
- Instruction List:
  1. `str rA, [rB, rC]`

### 3.8 Group 7 Instructions

- Encoding: 1110 aaaa bbbb cccc
  - a: general-purpose register rA
  - b: general-purpose register rB
  - c: general-purpose register rC
- Instruction List:
  1. `add rA, rB, rC`