

I Introduction

I.A General Information

- Addresses are 32-bit.
- Big-endian byte ordering is used.
- Bytes are octets (8 bits).
- Instructions must be aligned to 16 bits, so jump and branch targets must also be aligned to 16 bits.
 - Branch offsets encoded into instructions must be 16-bit aligned, or in other words bit 0 of the branch offset must be **0b0**

I.B Registers

There are sixteen general-purpose registers (all of which are 32-bit): **r0**, **r1**, **r2**, ..., **r11**, **r12**, **lr** (link register, the return address of **bl** and **jl**), **fp** (frame pointer), and **sp** (stack pointer).

The program counter, **pc**, is 32 bits long, as addresses are 32-bit.

Here are the special-purpose registers:

- **flags**: arithmetic/logic **FLAGS**; (reg encoding: **0x0**)
- **ids**: Interrupt DeStination: the address to jump to upon an interrupt being serviced (also known as the interrupt vector); (reg encoding: **0x1**)
- **ira**: Interrupt Return Address: the address that was jumped from upon an interrupt being serviced; (reg encoding: **0x2**)
- **ie**: IRQ Enable flag: flag indicating whether IRQs are disabled (**0x0**) or enabled (**0x1**); note that this flag starts with a value of **0x0**; (reg encoding: **0x3**)
- **ity**: Interrupt TYpe: flag indicating whether the most recently taken interrupt is an IRQ (**0x0**) or a **swi** (**0x1**) (reg encoding: **0x4**)
- **sty**: Software interrupt TYpe: **swi**'s argument. For **swi rA, #simm**, this is the value **rA + simm** (reg encoding: **0x5**)
- Note: All other encodings for special-purpose registers are reserved.

Here are the bits of **flags**:

- Zero (**Z**): (**flags** bit 0)
- Carry (**C**): (**flags** bit 1)
- oVerflow (**V**): (**flags** bit 2)
- Negative (**N**): (**flags** bit 3)
- Note: All other bit positions of **flags** are reserved.

II Instruction Set

II.A Instruction Group 0: **pre** and **lpre**

For **pre**, the following encoding is used, with each character representing one bit:

0000 iiii iiii iiii, where

- **i** is a 12-bit constant.

For **lpre**, the following encoding is used, with each character representing one bit:

0001 0iii iiii iiii iiii iiii iiii iiii, where

- **i** is a 27-bit constant.

pre and **lpre** are mechanisms by which immediates larger than normal can be used, essentially acting like variable width instructions.

There is no mechanism in the assembly language itself to use **pre** or **lpre** as instructions. Instead, it is expected that the assembler or linker will be the one to insert **pre** or **lpre** as needed if an immediate is too large for a particular instruction.

For non-branch instructions:

- If `pre` is used, the immediate field of the `pre` instruction will form bits [16:5] of the immediate of the next non-index instruction. The 17-bit immediate will then be sign-extended to 32 bits. Sign-extension will be performed on the 17-bit immediate even if, had there been no `pre`, the 5-bit immediate would have been zero-extended.
- On the other hand, if `lpre` is used, the immediate field of the `lpre` instruction will form bits [31:5] of the immediate of the next non-index instruction.

For branch instructions (group 3):

- if `pre` is used, the immediate field of the `pre` instruction will form bits [20:9] of the immediate of the next non-index instruction. The 21-bit immediate will then be sign-extended to 32 bits.
- On the other hand, if `lpre` is used, the immediate field of the `lpre` instruction will form bits [31:9] of the immediate of the next non-index instruction.

II.A.1 Handling of `pre`, `lpre`, and `index`

When a `pre` or `lpre` instruction is found, `pre` or `lpre` will be considered to be “in effect”. This condition lasts for one or two instructions after the `pre` or `lpre` instruction, depending on whether or not `index` was in effect.

`index` is an instruction (defined later) that allows a subsequent load or store instruction to perform `base_reg + index_reg` indexing. When an `index` instruction is found, it is considered to be in effect. Like `pre` and `lpre`, `index` is inserted automatically by the assembler.

`index` can be combined with `pre` or `lpre`, and it does not matter whether `index` or the `pre/lpre` instruction came first.

When `pre`, `lpre`, or `index` is in effect, IRQs will not be serviced.

Pseudo code for handling the how `pre`, `lpre`, and `index` are to be handled regarding whether or not they are “in effect” is as follows:

```
function handlePreLpreIndex(input in, output out) {
  when (!out.instr.isLpre()) {
    when (in.instr.isPre()) {
      when (
        in.state.pre.haveIt
        || in.state.lpre.haveIt
      ) {
        // invalid instruction
        out.state.pre.haveIt := False
        out.state.lpre.haveIt := False
        out.state.index.haveIt := False
        out.instr := NOP
        out.state.canServiceIrq := True
      } otherwise {
        out.state.pre.haveIt := True
        out.state.pre.data := in.instr[11:0]
        out.instr := in.instr
        out.state.canServiceIrq := False
      }
    } elseif (in.instr.isLpre()) {
      when (
        in.state.pre.haveIt
        || in.state.lpre.haveIt
      ) {
        // invalid instruction
        out.state.pre.haveIt := False
        out.state.lpre.haveIt := False
        out.state.index.haveIt := False
        out.instr := NOP
        out.state.canServiceIrq := True
      } otherwise {
```

```

        out.state.lpre.haveIt := True
        out.instr := in.instr
        out.state.canServiceIrq := False
        out.state.lpre.data[26:16] := in.instr[10:0]
    }
} elseif (in.instr.isIndex()) {
    when (
        in.state.index.haveIt
    ) {
        // invalid instruction
        out.state.pre.haveIt := False
        out.state.lpre.haveIt := False
        out.state.index.haveIt := False
        out.instr := NOP
        out.state.canServiceIrq := True
    } otherwise {
        out.state.index.haveIt := True
        out.instr := in.instr
        out.state.canServiceIrq := False
    }
} otherwise {
    out.state.canServiceIrq := !(
        in.state.pre.haveIt
        || in.state.lpre.haveIt
        || in.state.index.haveIt
    )
    out.instr := instr

    // Whenever we see an instruction other than `pre`, `lpre`, or `index`,
    // that means those instructions stop being "in effect".
    out.state.pre.haveIt := False
    out.state.lpre.haveIt := False
    out.state.index.haveIt := False
}
} otherwise { // when (out.instr.isLpre())
    out.state.lpre.data[15:0] := in.instr
}
}

```

II.B Instruction Group 1

The following encoding is used, with each character representing one bit:

001i iiii oooo aaaa, where

- **i** is a 5-bit sign-extended or zero-extended immediate, and is denoted **simm** when sign-extended or **imm** when zero-extended. Also, **simm** or **imm** can be expanded with **pre** or **lpre**.
- **a** encodes register **rA**
- **o** is the opcode

Here is a list of instructions from this encoding group.

- Opcode 0x0: add rA, #simm
- Opcode 0x1: add rA, pc, #simm
 - Effect: $rA \leftarrow pc + simm + 2$;
- Opcode 0x2: add rA, sp, #simm
- Opcode 0x3: add rA, fp, #simm
- Opcode 0x4: cmp rA, #simm
 - Effect: Compare rA to simm.
 - Affectable flags: Z, C, V, N
- Opcode 0x5: cpy rA, #simm
 - Effect: Copy an immediate value into rA
- Opcode 0x6: lsl rA, #imm

- Effect: Logical shift left
- Opcode 0x7: lsr rA, #imm
 - Effect: Logical shift right
- Opcode 0x8: asr rA, #imm
 - Effect: Arithmetic shift right
- Opcode 0x9: and rA, #simm
 - Effect: Bitwise AND
- Opcode 0xa: orr rA, #simm
 - Effect: Bitwise OR
- Opcode 0xb: xor rA, #simm
 - Effect: Bitwise XOR
- Opcode 0xc: ze rA, #imm
 - Effect: Set rA[31:imm] to zero.
- Opcode 0xd: se rA, #imm
 - Effect: Sign-extend rA[imm:0] to 32 bits, then copy that value to rA.
- Opcode 0xe: swi rA, #simm
 - Effect: Call software interrupt number rA + simm.
- Opcode 0xf: swi #imm
 - Effect: Call software interrupt number imm.

II.C Instruction Group 2

The following encoding is used, with each character representing one bit:

010f oooo bbbb aaaa, where

- o is the opcode
- b encodes register rB
- a encodes register rA
- f is encoded as 0 if this instruction cannot affect flags and encoded 1 if this instruction is permitted to affect flags. Note that `cmp` is permitted to affect flags regardless of this bit.

Here is a list of instructions from this encoding group.

- Opcode 0x0: add rA, rB
 - Mnemonic for when flags not affected: `add`
 - Mnemonic for when flags affected: `add.f`
 - Affectable flags: Z, C, V, N
- Opcode 0x1: sub rA, rB
 - Mnemonic for when flags not affected: `sub`
 - Mnemonic for when flags affected: `sub.f`
 - Affectable flags: Z, C, V, N
- Opcode 0x2: add rA, sp, rB
 - Mnemonic for when flags not affected: `add`
 - Mnemonic for when flags affected: `add.f`
 - Affectable flags: Z, C, V, N
- Opcode 0x3: add rA, fp, rB
 - Mnemonic for when flags not affected: `add`
 - Mnemonic for when flags affected: `add.f`
 - Affectable flags: Z, C, V, N
- Opcode 0x4: cmp rA, rB
 - Effect: Compare rA to rB. `cmp` is *always* able to affect flags, independent of the encoded f bit of the instruction.
 - Affectable flags: Z, C, V, N
- Opcode 0x5: cpy rA, rB
 - Mnemonic for when flags not affected: `cpy`
 - Mnemonic for when flags affected: `cpy.f`

- Effect: Copy `rB` into `rA`
- Affectable flags: `Z`, `N`
- Opcode `0x6`: `lsl rA, rB`
 - Mnemonic for when flags not affected: `lsl`
 - Mnemonic for when flags affected: `lsl.f`
 - Effect: Logical shift left
 - Affectable flags: `Z`, `N`
- Opcode `0x7`: `lsr rA, rB`
 - Mnemonic for when flags not affected: `lsr`
 - Mnemonic for when flags affected: `lsr.f`
 - Effect: Logical shift right
 - Affectable flags: `Z`, `N`
- Opcode `0x8`: `asr rA, rB`
 - Mnemonic for when flags not affected: `asr`
 - Mnemonic for when flags affected: `asr.f`
 - Effect: Arithmetic shift right
 - Affectable flags: `Z`, `N`
- Opcode `0x9`: `and rA, rB`
 - Mnemonic for when flags not affected: `and`
 - Mnemonic for when flags affected: `and.f`
 - Effect: Bitwise AND
 - Affectable flags: `Z`, `N`
- Opcode `0xa`: `orr rA, rB`
 - Mnemonic for when flags not affected: `orr`
 - Mnemonic for when flags affected: `orr.f`
 - Effect: Bitwise OR
 - Affectable flags: `Z`, `N`
- Opcode `0xb`: `xor rA, rB`
 - Mnemonic for when flags not affected: `xor`
 - Mnemonic for when flags affected: `xor.f`
 - Effect: Bitwise XOR
 - Affectable flags: `Z`, `N`
- Opcode `0xc`: `adc rA, rB`
 - Mnemonic for when flags not affected: `adc`
 - Mnemonic for when flags affected: `adc.f`
 - Effect: Add with Carry, using the formula $rA + rB + \text{flags.C}$ to compute the value that will be written into `rA`.
 - Affectable flags: `Z`, `C`, `V`, `N`
- Opcode `0xd`: `sbc rA, rB`
 - Mnemonic for when flags not affected: `sbc`
 - Mnemonic for when flags affected: `sbc.f`
 - Effect: Subtract with Borrow, using the formula $rA + (\sim rB) + \text{flags.C}$ to compute the value that will be written into `rA`.
 - Affectable flags: `Z`, `C`, `V`, `N`
- Opcode `0xe`: `cmpbc rA, rB`
 - Effect: Compare `rA` to `rB`, but with carry-in and a different effect for setting the `flags.Z`. `cmpbc` is *always* able to affect `flags`, independent of the encoded `f` bit of the instruction.
 - Note: this instruction acts much like `sbc rA, rB`, but without storing the subtraction's result into `rA`. However, this instruction sets the `Z` flag to `prev(flags.Z) AND ((rA + (~rB) + flags.C) == 0)`
 - Affectable flags: `Z`, `C`, `V`, `N`

II.D Instruction Group 3: Relative Branches

The following encoding is used, with each character representing one bit:

011i iiii iiii oooo, where

- i is a 9-bit sign-extended immediate, which can be expanded by `pre` or `lpre`, and is denoted `simm`
- o is the opcode

Here is a list of instructions from this encoding group.

- Opcode 0x0: `bl simm`
 - Name: Branch and Link
 - Description: Relative call
 - Effect: `lr <= pc + 2; pc <= pc + simm + 2;`
- Opcode 0x1: `bra simm`
 - Name: BRanch Always
 - Description: Unconditional relative branch
 - Effect: `pc <= pc + simm + 2;`
- Opcode 0x2: `beq simm`
 - Name: Branch if EQual
 - Effect: `if (flags.Z) pc <= pc + simm + 2;`
- Opcode 0x3: `bne simm`
 - Name: Branch if Not Equal
 - Effect: `if (!flags.Z) pc <= pc + simm + 2;`
- Opcode 0x4: `bmi simm`
 - Name: Branch if MInus
 - Effect: `if (flags.N) pc <= pc + simm + 2;`
- Opcode 0x5: `bpl simm`
 - Name: Branch if PPlus
 - Effect: `if (!flags.N) pc <= pc + simm + 2;`
- Opcode 0x6: `bvs simm`
 - Name: Branch if oVerflow Set
 - Effect: `if (flags.V) pc <= pc + simm + 2;`
- Opcode 0x7: `bvc simm`
 - Name: Branch if oVerflow Clear
 - Effect: `if (!flags.V) pc <= pc + simm + 2;`
- Opcode 0x8: `bgeu simm`
 - Name: Branch if Greater than or Equal Unsigned
 - Effect: `if (flags.C) pc <= pc + simm + 2;`
- Opcode 0x9: `bltu simm`
 - Name: Branch if Less Than Unsigned
 - Effect: `if (!flags.C) pc <= pc + simm + 2;`
- Opcode 0xa: `bgtu simm`
 - Name: Branch if Greater Than Unsigned
 - Effect: `if (flags.C AND !flags.Z) pc <= pc + simm + 2;`
- Opcode 0xb: `bleu simm`
 - Name: Branch if Less than or Equal Unsigned
 - Effect: `if (!flags.C OR flags.Z) pc <= pc + simm + 2;`
- Opcode 0xc: `bges simm`
 - Name: Branch if Greater than or Equal Signed
 - Effect: `if (!(flags.N XOR flags.V)) pc <= pc + simm + 2;`
- Opcode 0xd: `blts simm`
 - Name: Branch if Less Than Signed
 - Effect: `if (flags.N XOR flags.V) pc <= pc + simm + 2;`
- Opcode 0xe: `bgts simm`
 - Name: Branch if Greater Than Signed

- Effect:


```
if (!(flags.N XOR flags.V) AND !flags.Z)
    pc <= pc + simm + 2;
```
- Opcode 0xf: bles simm
 - Name: Branch if Less than or Equal Signed
 - Effect:


```
if ((flags.N XOR flags.V) OR flags.Z)
    pc <= pc + simm + 2;
```

II.E Instruction Group 4

The following encoding is used, with each character representing one bit:

100o 0ooo bbbb aaaa, where

- o is the opcode
- b encodes register rB or register sC, where sC is one of the special-purpose registers
- a encodes register rA or register sA, where sA is one of the special-purpose registers

Here is a list of instructions from this encoding group.

- Opcode 0x0: jl rA
 - Effect: lr <= pc + 2; pc <= rA;
- Opcode 0x1: jmp rA
 - Effect: pc <= rA;
- Opcode 0x2: jmp ira
 - Effect: pc <= ira;
- Opcode 0x3: reti
 - Effect: enables IRQs (by copying 0x1 into ie) and performs pc <= ira;
- Opcode 0x4: ei
 - Effect: copy 1 into ie.
- Opcode 0x5: di
 - Effect: copy 0 into ie.
- Opcode 0x6: push rA, rB
 - Effect: pushes rA onto the stack, using rB as the stack pointer, post-decrementing rB.
 - This instruction does nothing when rA is the same register as rB.
 - Note: As a pseudo instruction, omitting “ , rB” will automatically select sp as the particular stack pointer.
- Opcode 0x7: push sA, rB
 - Effect: pushes sA onto the stack, using rB as the stack pointer, post-decrementing rB.
 - Note that sA is considered to be 32-bit for the purpose of the store to memory and decrementing rB, even if sA is flags or ie.
 - Note: As a pseudo instruction, omitting “ , rB” will automatically select sp as the particular stack pointer.
- Opcode 0x8: pop rA, rB
 - Effect: pops rA off the stack, using rB as the stack pointer, pre-incrementing rB.
 - This instruction does nothing when rA is the same register as rB.
 - Note: As a pseudo instruction, omitting “ , rB” will automatically select sp as the particular stack pointer.
- Opcode 0x9: pop sA, rB
 - Effect: pops sA off the stack, using rB as the stack pointer, pre-incrementing rB.
 - Note that sA is considered to be 32-bit for the purpose of the load from memory and incrementing rB, even if sA is flags or ie.
 - Note: As a pseudo instruction, omitting “ , rB” will automatically select sp as the particular stack pointer.
- Opcode 0xa: pop pc, rB
 - Effect: pops pc off the stack, using rB as the stack pointer, pre-incrementing rB.

- Note that `pc` is considered to be 32-bit for the purpose of the load from memory and incrementing `rB`, even if `pc` is `flags` or `ie`.
- Note: As a pseudo instruction, omitting “`, rB`” will automatically select `sp` as the particular stack pointer.
- Opcode `0xb`: `mul rA, rB`
 - Effect: `rA <= rA * rB`;
- Opcode `0xc`: `udiv rA, rB`
 - Effect: `rA <= u32(rA) / u32(rB)`;
- Opcode `0xd`: `sdiv rA, rB`
 - Effect: `rA <= s32(rA) / s32(rB)`;
- Opcode `0xe`: `umod rA, rB`
 - Effect: `rA <= u32(rA) \\/ u32(rB)`;
- Opcode `0xf`: `smod rA, rB`
 - Effect: `rA <= s32(rA) \\/ s32(rB)`;
- Opcode `0x10`: `lumul rA, rB`
 - Effect: This instruction multiplies `rA` by `rB`, performing an unsigned 32-bit by 32-bit -> 64-bit multiply, storing result in `concat{r0, r1}`.
- Opcode `0x11`: `lsmul rA, rB`
 - Effect: This instruction multiplies `rA` by `rB`, performing a signed 32-bit by 32-bit -> 64-bit multiply, storing result in `concat{r0, r1}`.
- Opcode `0x12`: `udiv64 rA, rB`
 - Effect: performs a 64-bit by 64-bit unsigned division of `concat{rA, r{A + 1}}` by `concat{rB, r{B + 1}}`, storing 64-bit result in `concat{rA, r{A + 1}}`.
 - Note: This instruction operates as if `rA` were encoded with (`A[0x0] == 0b0`) and `rB` were encoded with (`B[0x0] == 0b0`),
 - Note: This instruction executes more quickly if `rB`'s value is `0x00000000`, i.e. if the operation is actually a 64-bit by 32-bit -> 64-bit unsigned divide.
- Opcode `0x13`: `sdiv64 rA, rB`
 - Effect: performs a 64-bit by 64-bit signed division of `concat{rA, r{A + 1}}` by `concat{rB, r{B + 1}}`, storing 64-bit result in `concat{rA, r{A + 1}}`.
 - Note: This instruction operates as if `rA` were encoded with (`A[0x0] == 0b0`) and `rB` were encoded with (`B[0x0] == 0b0`),
 - Note: This instruction executes more quickly if `rB` is equal to bits `[63:32]` of `s64(r{B+1})`.
- Opcode `0x14`: `umod64 rA, rB`
 - Effect: performs a 64-bit by 64-bit unsigned modulo of `concat{rA, r{A + 1}}` by `concat{rB, r{B + 1}}`, storing 64-bit result in `concat{rA, r{A + 1}}`.
 - Note: This instruction operates as if `rA` were encoded with (`A[0x0] == 0b0`) and `rB` were encoded with (`B[0x0] == 0b0`),
 - Note: This instruction executes more quickly if `rB`'s value is `0x00000000`, i.e. if the operation is actually a 64-bit by 32-bit -> 64-bit unsigned modulo.
- Opcode `0x15`: `smod64 rA, rB`
 - Effect: performs a 64-bit by 64-bit signed modulo of `concat{rA, r{A + 1}}` by `concat{rB, r{B + 1}}`, storing 64-bit result in `concat{rA, r{A + 1}}`.
 - Note: This instruction operates as if `rA` were encoded with (`A[0x0] == 0b0`) and `rB` were encoded with (`B[0x0] == 0b0`),
 - Note: This instruction executes more quickly if `rB` is equal to bits `[63:32]` of `s64(r{B+1})`.
- Opcode `0x16`: `ldub rA, [rB]`
 - Effect: Load an 8-bit value from memory at address computed as `rB + index_reg`, zero-extend the 8-bit value to 32 bits, then put the zero-extended 32-bit value into `rA`.
 - The `index_reg` value is guaranteed to be zero unless an `index` is in effect.
 - Shorthand for having the assembler insert an `index rC` instruction before this one: `ldub rA, [rB, rC]`
- Opcode `0x17`: `ldsb rA, [rB]`

- Effect: Load an 8-bit value from memory at address computed as $rB + \text{index_reg}$, sign-extend the 8-bit value to 32 bits, then put the sign-extended 32-bit value into rA .
- The `index_reg` value is guaranteed to be zero unless an `index` is in effect.
- Shorthand for having the assembler insert an `index rC` instruction before this one: `ldsb rA, [rB, rC]`
- Opcode 0x18: `lduh rA, [rB]`
 - Effect: Load a 16-bit value from memory at address computed as $rB + \text{index_reg}$, zero-extend the 16-bit value to 32 bits, then put the zero-extended 32-bit value into rA .
 - The `index_reg` value is guaranteed to be zero unless an `index` is in effect.
 - Shorthand for having the assembler insert an `index rC` instruction before this one: `lduh rA, [rB, rC]`
- Opcode 0x19: `ldsh rA, [rB]`
 - Effect: Load a 16-bit value from memory at address computed as $rB + \text{index_reg}$, sign-extend the 16-bit value to 32 bits, then put the zero-extended 32-bit value into rA .
 - The `index_reg` value is guaranteed to be zero unless an `index` is in effect.
 - Shorthand for having the assembler insert an `index rC` instruction before this one: `ldsh rA, [rB, rC]`
- Opcode 0x1a: `stb rA, [rB]`
 - Effect: Store $rA[7:0]$ to memory at the address computed as $rB + \text{index_reg}$.
 - The `index_reg` value is guaranteed to be zero unless an `index` is in effect.
 - Shorthand for having the assembler insert an `index rC` instruction before this one: `stb rA, [rB, rC]`
- Opcode 0x1b: `sth rA, [rB]`
 - Effect: Store $rA[15:0]$ to memory at the address computed as $rB + \text{index_reg}$.
 - The `index_reg` value is guaranteed to be zero unless an `index` is in effect.
 - Shorthand for having the assembler insert an `index rC` instruction before this one: `sth rA, [rB, rC]`
- Opcode 0x1c: `cpy rA, sB`
 - Effect: $rA \leq sB$;
- Opcode 0x1d: `cpy sA, rB`
 - Effect: $sA \leq rB$;
- Opcode 0x1e: `cpy sA, sB`
 - Effect: $sA \leq sB$;
- Opcode 0x1f: `index rA`
 - Effect: Performs `index_reg <= rA`; and stores that `index` is in effect.
 - Note: If `index` is in effect and the current instruction is `index`, the current instruction will be treated as a NOP, and `index` will stop being in effect.
 - Note: `pre` and `index` can be combined with one another (though this is only useful for `ldr` and `str`).
 - Note: A non-`pre` instruction following `index` will store that that `index` is not in effect any more. (It will also store that `pre` is not in effect any more).
 - Note: If `index` is in effect, the current instruction cannot be interrupted by an IRQ.
 - Note: Any time `index` stops being in effect, `pre` will stop being in effect as well.

II.F Instruction Group 5: Immediate Indexed Load

The following encoding is used, with each character representing one bit:

101i iiii bbbb aaaa, where

- `i` is a 5-bit sign-extended immediate, which can be expanded by `pre` or `lpre`, and is denoted `simm`
- `b` encodes register rB
- `a` encodes register rA

The one instruction from this encoding group is `ldr rA, [rB, #simm]`. This is a 32-bit load into rA , where the effective address to load from is computed as $rB + \langle \text{index_reg} \rangle + \text{simm}$, using the sign-extended form of `simm`.

The `<index_reg>` value is guaranteed to be zero unless an `index` is in effect.

The following pseudo instructions exist within the assembler for this encoding group:

- `ldr rA, [rB]`
 - This pseudo instruction assembles to the following:
 - `ldr rA, [rB, #0x0]`
- `ldr rA, [rB, rC]`
 - This pseudo instruction assembles to the following:
 - `index rC`
 - `ldr rA, [rB, #0x0]`
- `ldr rA, [rB, rC, #simm]`
 - This pseudo instruction assembles to the following:
 - `index rC`
 - `ldr rA, [rB, #simm]`

II.G Instruction Group 6: Immediate Indexed Store

The following encoding is used, with each character representing one bit:

110i iiii bbbb aaaa, where

- `i` is a 5-bit sign-extended immediate, which can be expanded by `pre` or `lpre`, and is denoted `simm`
- `b` encodes register `rB`
- `a` encodes register `rA`

The one instruction from this encoding group is `str rA, [rB, #simm]`. This is a 32-bit store of `rA`, where the effective address to store to is computed as `<index_reg> + rB + simm`, using the sign-extended form of `simm`.

The `<index_reg>` value is guaranteed to be zero unless an `index` is in effect.

The following pseudo instructions exist within the assembler for this encoding group:

- `str rA, [rB]`
 - This pseudo instruction assembles to the following:
 - `str rA, [rB, #0x0]`
- `str rA, [rB, rC]`
 - This pseudo instruction assembles to the following:
 - `index rC`
 - `str rA, [rB, #0x0]`
- `str rA, [rB, rC, #simm]`
 - This pseudo instruction assembles to the following:
 - `index rC`
 - `str rA, [rB, #simm]`

II.H Instruction Group 7, Subgroup 0b00:

Extra 8-bit and 16-bit Ops} The following encoding is used, with each character representing one bit:

1110 0woo bbbb aaaa, where

- `w` is the operation width
 - When `0b0`: 8-bit operation
 - When `0b1`: 16-bit operation
- `o` is the opcode
- `b` encodes register `rB`
- `a` encodes register `rA`

Here is a list of instructions from this encoding group.

- Opcode `0x0`:
 - `w` value `0b0`: `cmpb rA, rB`
 - Effect: Compare `rA[7:0]` to `rB[7:0]`
 - Affectable flags: `Z`, `C`, `V`, `N`

- w value 0b1: cmph rA, rB
 - Effect: Compare rA[15:0] to rB[15:0]
 - Affectable flags: Z, C, V, N
- Opcode 0x1:
 - w value 0b0: lsrB rA, rB
 - Effect: Logical shift right rA[7:0] by rB
 - w value 0b1: lsrh rA, rB
 - Effect: Logical shift right rA[15:0] by rB
- Opcode 0x2:
 - w value 0b0: asrb rA, rB
 - Effect: Arithmetic shift right rA[7:0] by rB
 - w value 0b1: asrh rA, rB
 - Effect: Arithmetic shift right rA[15:0] by rB

II.I Instruction Group 7, Subgroup 0b010: Extra load/store instructions

The following encoding is used, with each character representing one bit:

1110 1000 bbbb aaaa, where

- o is the opcode
- b encodes register rB or sB
- a encodes register sA

Here is a list of instructions from this encoding group.

- Opcode 0x0: ldr sA, [rB]
 - Effect: 32-bit load of sA from memory at address held in rB.
- Opcode 0x1: ldr sA, [sB]
 - Effect: 32-bit load of sA from memory at address held in sB.
- Opcode 0x2: str sA, [rB]
 - Effect: 32-bit store of sA to memory at address held in rB.
- Opcode 0x3: str sA, [sB]
 - Effect: 32-bit store of sA to memory at address held in sB.

II.J Instruction Group 7, Subgroup 0b0110: Icache Flush Instruction

The following encoding is used, with each character representing one bit:

1110 1100 0000 0000

The one instruction from this encoding group is icflush, which invalidates the instruction cache entirely.