CS61C Spring 2026

Precheck: Inst. Trans., CALL

Discussion 6

1 Instruction Translation Pre-Check

1.1 True or False: In RISC-V, the opcode field of an instruction determines its type (R-Type, S-Type, etc.).

Answer: True.

The opcode field of an instruction uniquely identifies the instruction type and allows us to identify the instruction format we're working with. The opcode is located in the lowest 7 bits of the machine instruction (bits 0-6).

1.2 Convert the following RISC-V registers into their binary representation:

Note that since we have 32 different registers in RISC-V, we need 5 bits to encode them.

s0: Looking at the 61C reference sheet, we can see that s0 refers to the x8 register. To get the final answer, we convert 8 into binary: `0b01000`.

Following the same procedure as above, we get the rest of the answers...

sp: `x2 = 0b00010`

x9: `x9 = 0b01001`

t4: `x29 = 0b11101`

1.3 True or False: In RISC-V, the instruction `li x5 0x44331416` will always be encoded in 32 bits when translated into binary.

Answer: False.

This is a bit of a trick question. It is true that every regular instruction in RISC-V will always be encoded in 32-bits. However, li is actually a pseudo-instruction! Recall that pseudo-instructions can translate into one or more RISC-V instructions. In this case, li will be translated into an addi and lui instruction. Therefore, `li x5 0x44331416` will actually be encoded in 64-bits, as it represents two RISC-V instructions.

1.4 True or False: We can use a branch instruction to move the PC by one byte.

Answer: False

Branch instruction offsets have an implicit zero as the least significant bit, so we can only move the PC in offsets divisible by 2 (refer back to Lecture 14 for an explanation why this is!).

The full offset for a branch instruction will be the 13-bit offset `{imm[12:1], 0}`, where we take the immediate bits from our instruction's binary encoding and add the implicit zero.

2 Instruction Translation

Recall that every instruction in RISC-V can be represented as a 32-bit binary value, which encodes the type of instruction, as well as any registers/immediates included in the instruction. To convert a RISC-V instruction to binary, and vice-versa, you can use the steps below. The 61C reference sheet will be very useful for conversions!

RISC-V ⟹ Binary

(a) Identify the instruction type (R, I, I*, S, B, U, or J)
(b) Find the corresponding instruction format
(c) Convert the registers and immediate value, if applicable, into binary
(d) Arrange the binary bits according to the instruction format, including the opcode bits (and possibly funct3/funct7 bits)

Binary ⟹ RISC-V

(a) Identify the instruction using the opcode (and possibly funct3/funct7) bits
(b) Divide the binary representation into sections based on the instruction format
(c) Translate the registers + immediate value
(d) Put the final instruction together based on instruction type/format

Below is an example of a series of RISC-V instructions with their corresponding binary translations.

example.S	example.bin

`main:`
`  addi  sp,sp,-4`
`  sw  ra,0(sp)`
`  addi  s0,sp,4`
`  mv  a0,a5`
`  call  printf`
`  ...`
	`...`
	`11111111110000010000000100010011`
	`00000000000100010010000000100011`
	`00000000010000010000010000010011`
	`00000000000000000000010100010011`
	`00000000010001000000000011101111`
	`...`

3 CALL Pre-Check

3.1 The compiler may output pseudoinstructions.

True. It is the job of the assembler to replace these pseudoinstructions.

3.2 The main job of the assembler is to perform optimizations on the assembly code.

False. That's the job of the compiler. The assembler is primarily responsible for replacing pseudoinstructions and resolving offsets.

3.3 The object files produced by the assembler are only moved, not edited, by the linker.

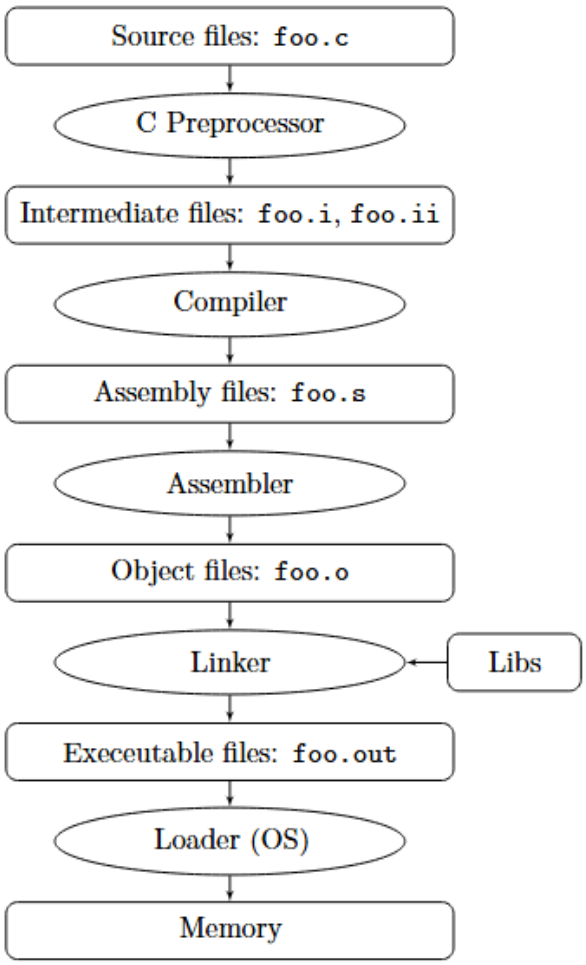
False. The linker needs to relocate all absolute address references.

3.4 The destination of all jump instructions is completely determined after linking.

False. Jumps relative to registers (i.e. from jalr instructions) are only known at run-time. Otherwise, you would not be able to call a function from different call sites.

4 CALL

The following is a diagram of the CALL stack detailing how C programs are built and executed by machines:



To translate a C program to an executable:

1. (C Preprocessor): translates all defined macros before passing to the compiler.
2. **Compiler**: Translates high-level language code (e.g. `foo.c`) to assembly
   - **Output**: Assembly language code (RISC-V) which may contain pseudoinstructions!
3. **Assembler**: Replaces pseudoinstructions and creates an *object file* with machine language, symbol table, relocation table, and debugging information.
   - **Output**: Object file (`foo.o`)
4. **Linker**: Combines multiple object files / libraries to create an executable.
   - **Output**: Executable machine code (e.g. `foo.out`).
5. **Loader**: Creates the environment to run machine code and begins execution.

4.1 How many passes through the code does the Assembler have to make? Why?

Two: The first finds all the label addresses, and the second resolves forward references while using these label addresses.

4.2 Which step in CALL resolves relative addressing? Absolute addressing?

The assembler usually handles relative addressing. The linker handles absolute addressing, resolving the references to memory locations outside.

4.3 Describe the six main parts of the object files outputted by the Assembler (Header, Text, Data, Relocation Table, Symbol Table, Debugging Information).

- Header: Sizes and positions of the other parts
- Text: The machine code
- Data: Binary representation of any data in the source file
- Relocation Table: Identifies lines of code that need to be "handled" by the Linker (jumps to external labels (e.g. lib files), references to static data)
- Symbol Table: List of file labels and data that can be referenced across files
- Debugging Information: Additional information for debuggers