J Compiler Overview

CIS 2400 Recitation 10

Recitation Outline

- HW10/11 Overview & the J language
- HW10/11 Structure
  - token.h
  - Program Structure
- LC4 Details
  - The Call Stack
  - Calling conventions
  - LC4 assembler Directives
- Tips
  - Testing
  - Error Handling

Overview

Overview

In this assignment, you will read in a .j file and create an equivalent LC4 .asm file

THAT'S IT

You don't have to worry about simulating anything, setting up the PC to run main first, etc.

The J Language: Basics

Stack-based language, similar to the RPN calculator from HW07

Literals:

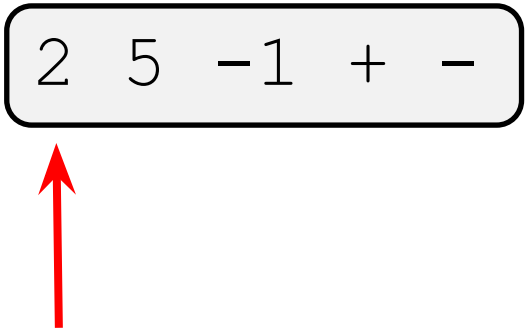
- All values can be represented as 16-bit 2C
- Positive or negative
- Decimal (digits and - sign) or hexadecimal (preceded by `0x`) formats

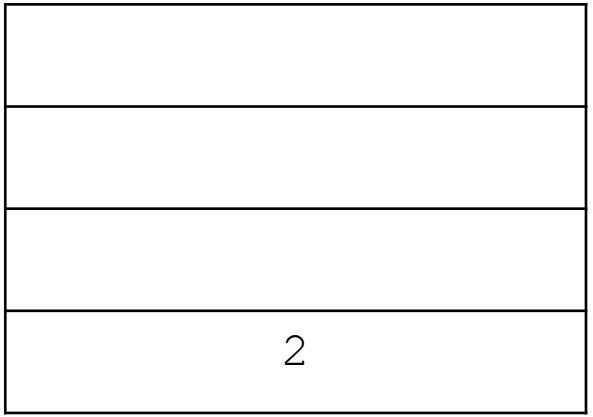
Example:

```
2 5 -1 + -
```

The J Language: Basics

Example:





The J Language: Basics

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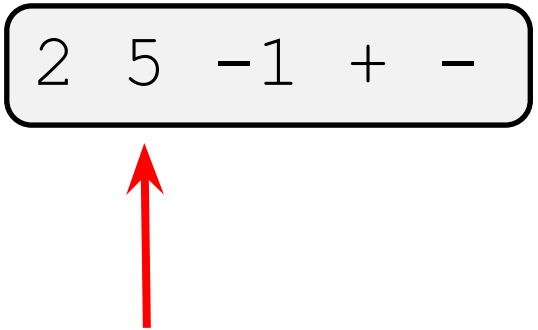

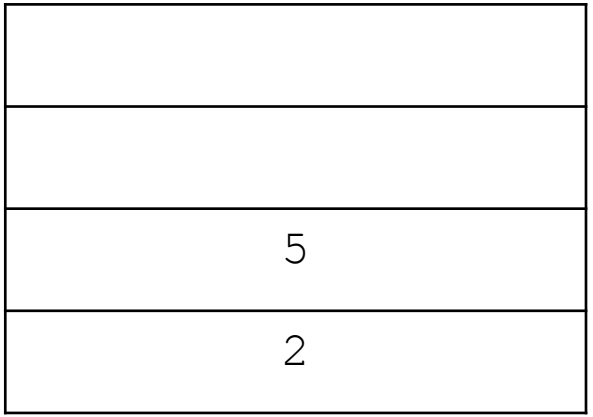

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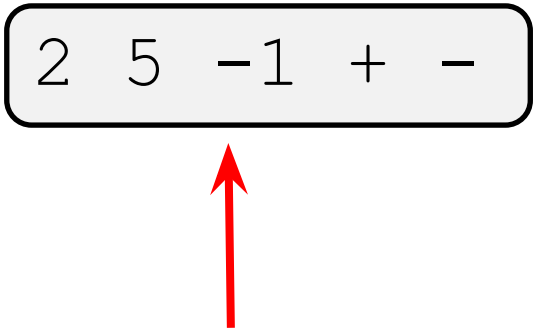

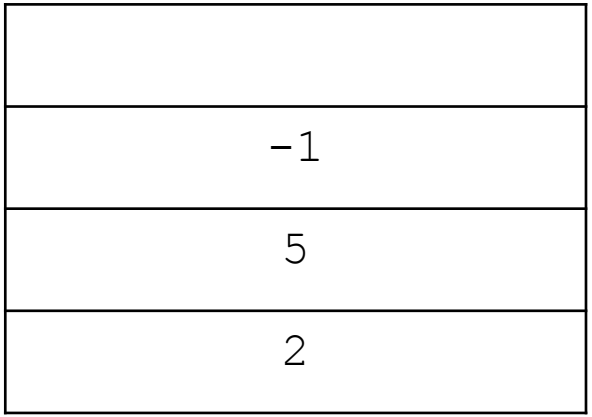

The J Language: Basics

Example:

```
2 5 -1 + -
```

4
2

Note that the top value of the stack is the first operand!

The J Language: Basics

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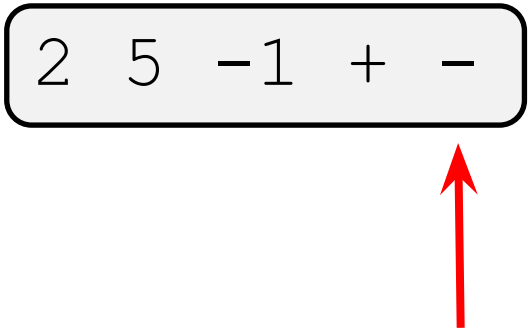

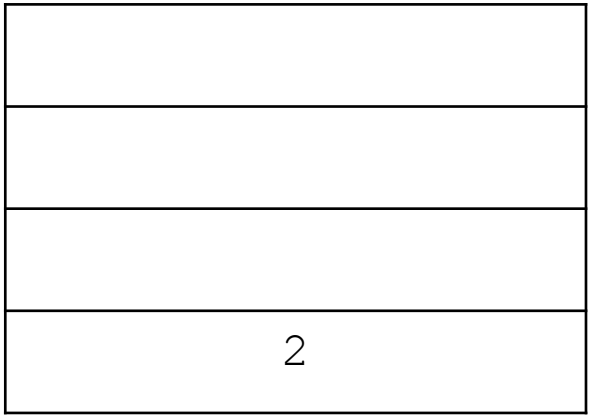

The J Language: Basics

Example:

```
1 3 2 0x7 + / *
```

The J Language: Basics

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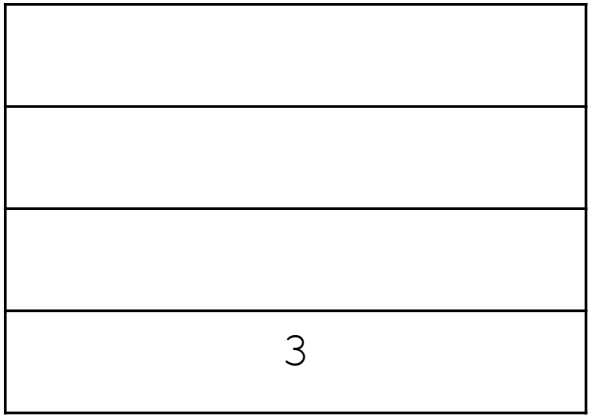


The J Language: Advanced

Not as simple as HW07:

- Other operators
- Comparison, rotations, etc.
- If/else/endif
- While loops
- Functions

If/Else/Endif

We can also have if/else/endif → conditional is met if value is non-zero

- Example

```
7 2 % if 1 else 0 endif
```

- Same example formatted differently (look familiar?)

```
7 2 %
if
    1
else
    0
endif
```

If/Else/Endif Example

```
7 2 % if 1 else 0 endif
```

If/Else/Endif Example

```
7 2 % if 1 else 0 endif
```

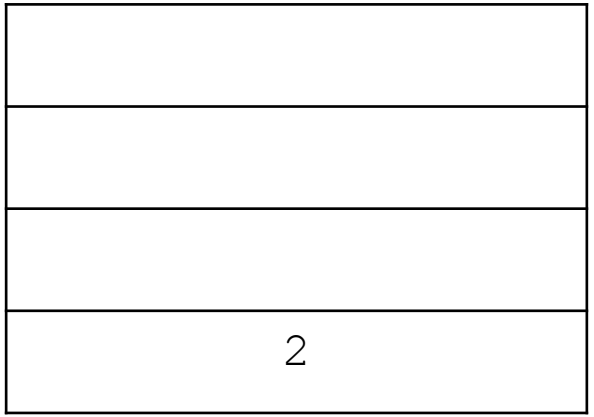
2
7

If/Else/Endif Example

```
7 2 % if 1 else 0 endif
```

Note that the Top value of the stack is the first operand!

2 % 7 = 2



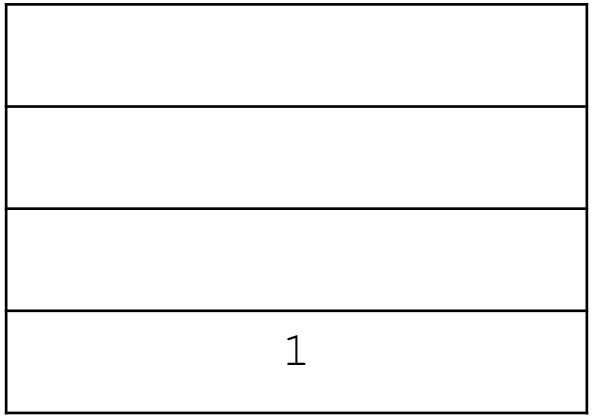
If/Else/Endif Example

```
7 2 % if 1 else 0 endif
```

If/Else/Endif Example

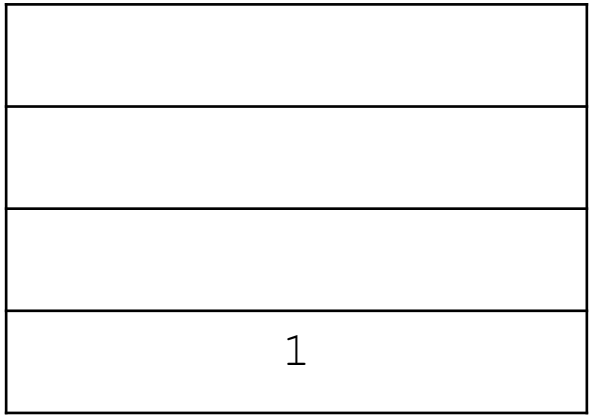
```
7 2 % if 1 else 0 endif
```

2 is nonzero, so we push 1 to the stack



If/Else/Endif Example

```
7 2 % if 1 else 0 endif
```



The else branch
is skipped over

If Statements – Some Caveats

- Some if statements may not have an else statement

```
7 2 % if 1 endif
```

- There can be programs that have many if statements
  - If you are using labels in LC4 (which you should do), you must have unique labels for the different IF/ELSE/ENDIF statements
- There may be some programs that have nested if/else/endif statements:

```
2 3 4 - if - if 2 else 1 endif else 0 endif
```

Stack Operations

If we had a stack (bottom) 3 4 5 (top)

drop	3 4
dup	3 4 5 5
swap	3 5 4
rot	4 5 3

J Functions

J can define functions with the token `defun`

Example function:

- First token after `defun` should be an identifier naming the function
- `argN` gets the nth value from top of the stack starting before the function is invoked.
- `return` returns from the function, placing the top value of the stack as the new top value of the stack for the caller.

```
defun square
arg1
dup * dup
return
```

J Functions: Example

Say we have the function

```
defun square
arg1
dup * dup
return
```

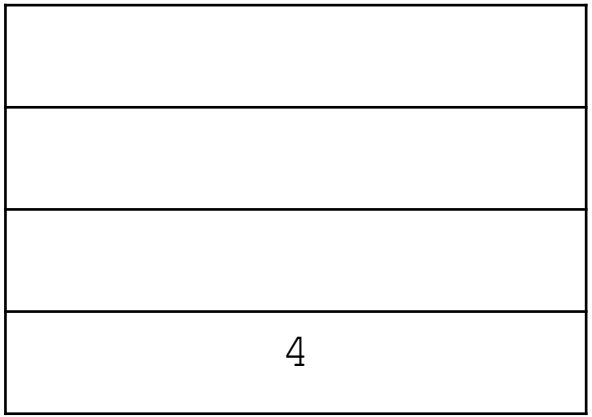
and call it with

```
4 square
```

J Functions: Example

```
defun square
arg1
dup * dup
return
```

```
4 square
```



J Functions: Example

```
defun square
arg1
dup * dup
return
```

```
4 square
```

Caller's portion of the stack (e.g. caller's stack frame)

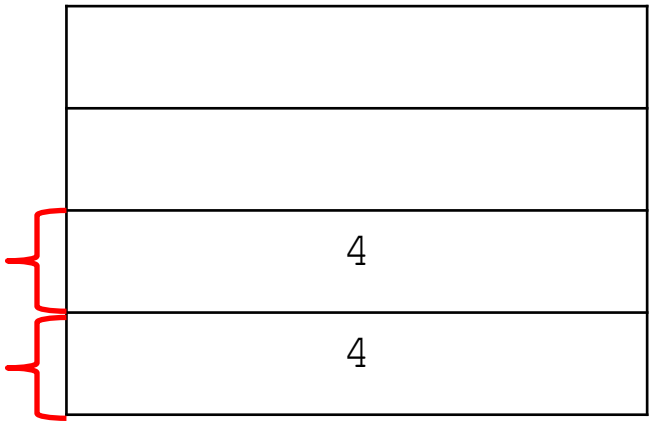
J Functions: Example

```
defun square
arg1
dup * dup
return
```

```
4 square
```

square's stack frame

caller's stack frame



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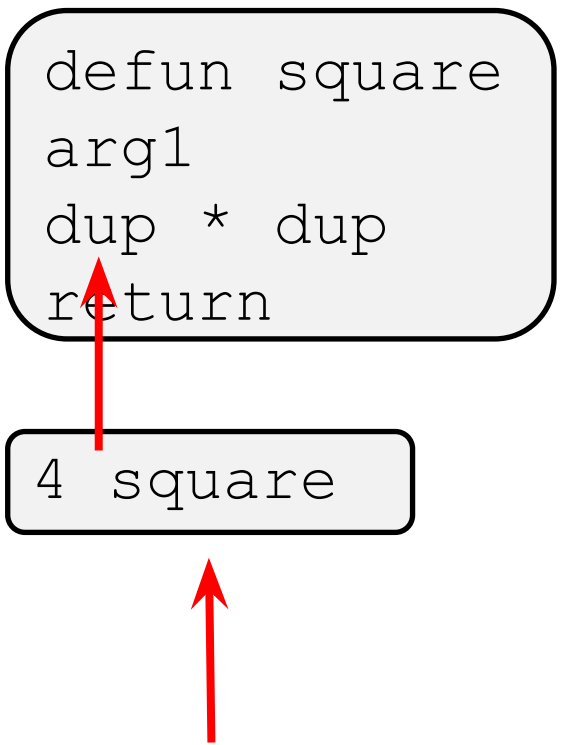
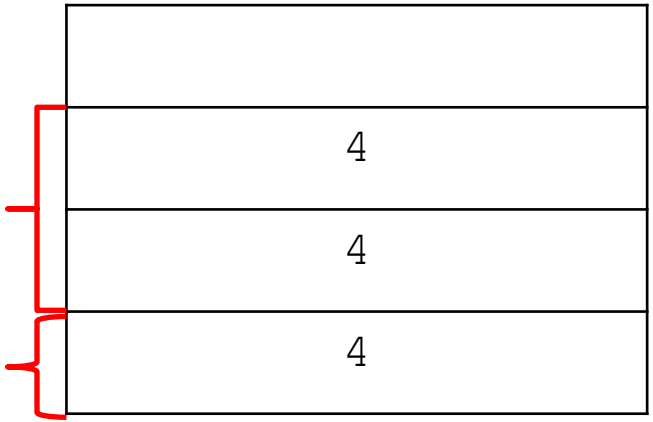
```



square's stack frame

caller's stack frame



J Functions: Example

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return
```
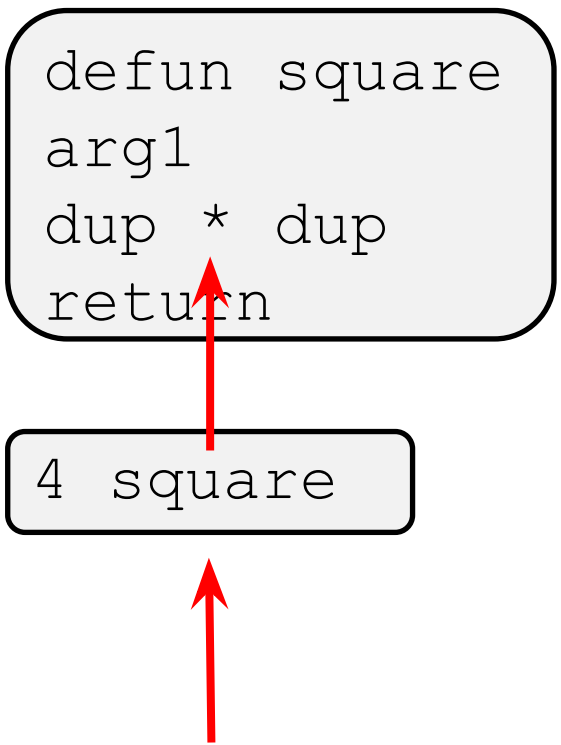

```
4 square
```



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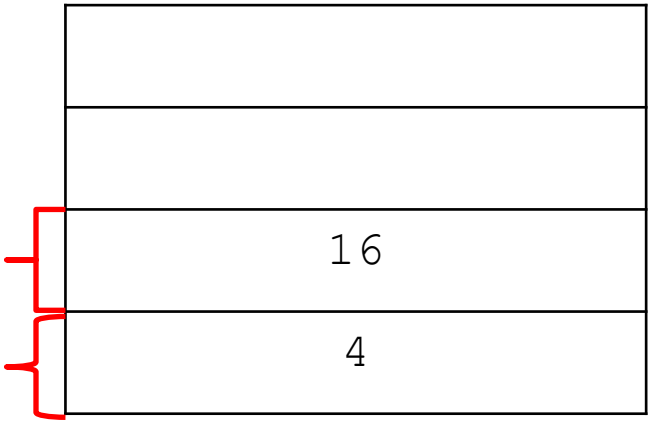

J Functions: Example

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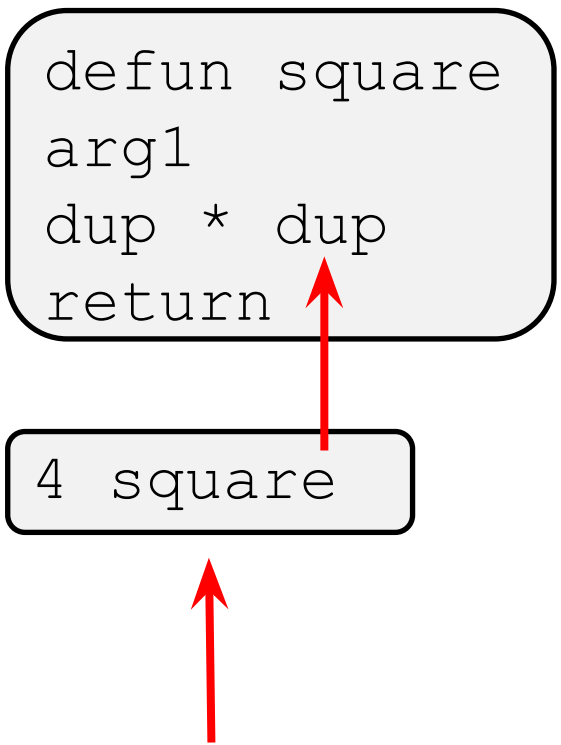
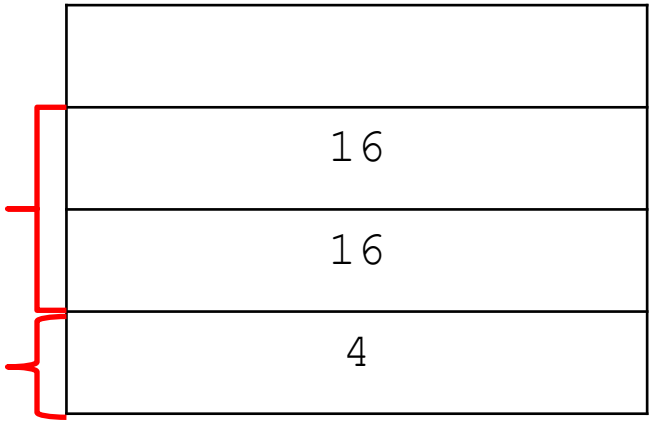
arg1
dup * dup
return
```

```
4 square
```



square's stack frame

caller's stack frame



J Functions: Example

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defun square
arg1
dup * dup
return
```
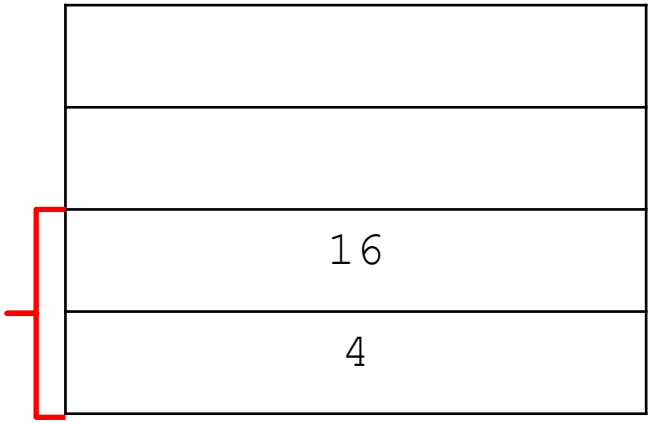

```
4 square
```

caller's stack frame



This is all J at a high level, many LC4 details left out (for now)

Code Structure

Getting Started

- To get started with the homework, we recommend that you implement token.c to read from a file and output tokens.
- A 'token' in a .j file can be 'arg1', '+', 'defun', etc.
- We represent a token with:

```
typedef struct {
  token_type type;
  int literal_value;
  int arg_no;
  char str[MAX_TOKEN_LENGTH];
} token;
```

Enum similar to INSN_TYPE

The value if the token is a literal (e.g. '5' or '0xCAFE')

Value of N for argN

Str value of a IDENT token (more on IDENT in a moment)

Getting Started

The token types are mostly self explanatory, with two exceptions (IDENT, LITERAL)

- DEFUN -> “defun” in the .j file
- ARG -> “arg1” or som other argN in the.j file
- Etc.

```
typedef enum { DEFUN, IDENT, RETURN,
               PLUS, MINUS, MUL, DIV, MOD,
               AND, OR, NOT,
               LT, LE, EQ, GE, GT,
               IF, ELSE, ENDIF, WHILE,
               DROP, DUP, SWAP, ROT,
               ARG, LITERAL, BAD_TOKEN } token_type;
```

LITERAL Token

- Used to represent an integer “literal” in j
- For example, in the program

```
7 5 4 + -
```

  7, 5 and 4 are literals.

- Can have a leading ‘-’ to mark the number as negative
  - Be careful! There is also a token that is just the ‘-’ symbol
- Can be in hexadecimal e.g.

```
0x7 5 0x0004 + -
```

IDENT Token

- Used to find tokens that identify a function
- In the example program, there are 3 ident tokens
- A token is an IDENT if it is not one of the other token types, starts with a letter and the following characters can be under scores '_', numbers, or other letters
- You can assume that all calls to functions are to defined functions and that there are no duplicate function names

```
defun square
arg1
dup *
return

defun main
4 square
return
```

token.h

- In token.h, we provide the declaration for the function:

```
int read_token(token *theToken, FILE *theFile);
```

  - Takes in a FILE* theFile to read from
  - Returns a token through theToken output parameter
  - Returns whether an error was encountered or not
- Many way to read the file:
  - Read the file line by line (using something like fgets)
  - Read the file string by string (probably using fscanf)
  - Read the file character by character (using fgetc)
  - Some combination of these
- You are also allowed to modify this function

Token Processing

With how J works, almost all tokens can be processed on their own (e.g. you don't have to read future tokens and/or remember pass tokens to process it)

There are two exceptions to this:

- Function definitions
  - Need to read the defun token and the next token which should be an IDENT for the function name
- The if/else/endif tokens
  - Need to know the labels to jump to, and handle nested if/else/endifs

Program Structure

Main program:

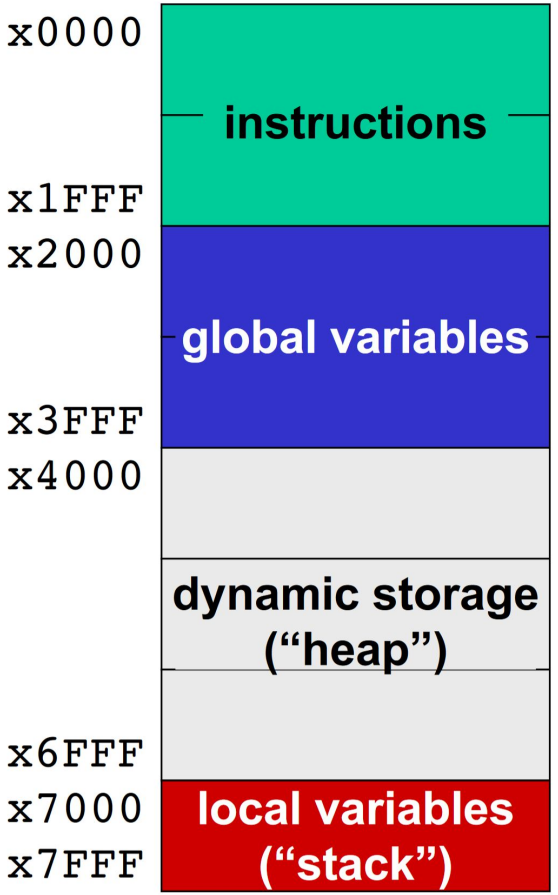
```
in_f = fopen(input_file_name)
out_f = fopen(output_file_name)
token
while readtoken(&token, in_f) not error:
   // write the assembly to out_f
   // based on what token is
```

This part is up to you, could create function(s) to handle this.

LC4 Details

The Call Stack

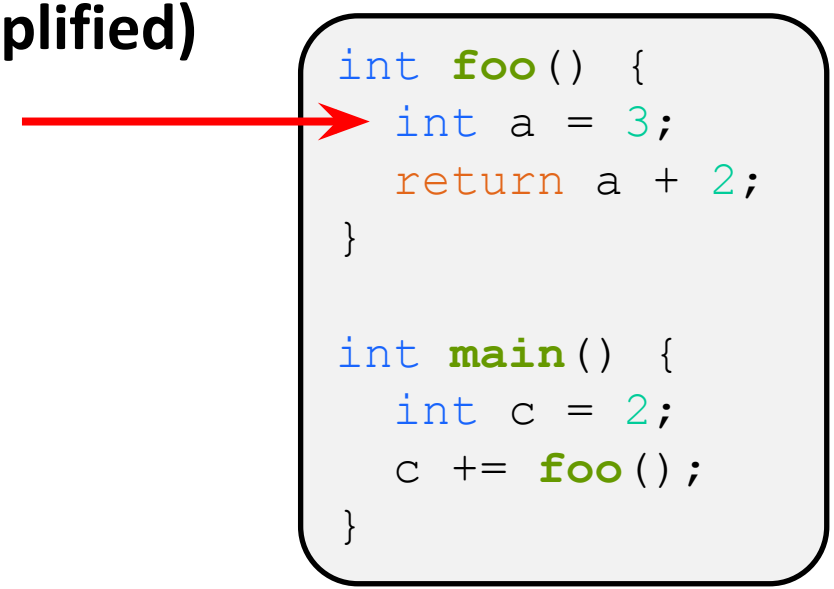
- A portion of memory used for keeping track of functions
- Each invocation/execution has a stack frame that is pushed onto the stack.
  - The stack frame contains the local variables, base pointer, and return address.

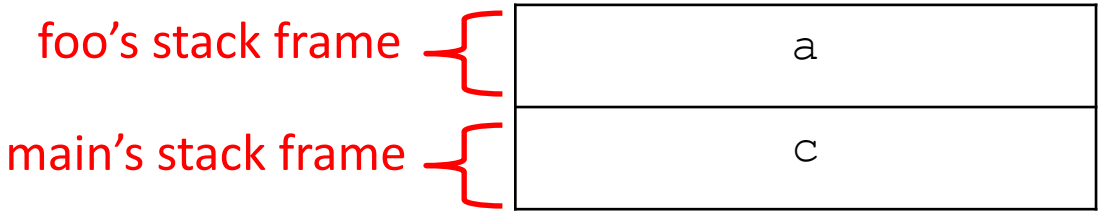


The Call Stack: C Example (simplified)

```
int foo() {
  int a = 3;
  return a + 2;
}

int main() {
  int c = 2;
  c += foo();
}
```

The Call Stack: C Example (simplified)





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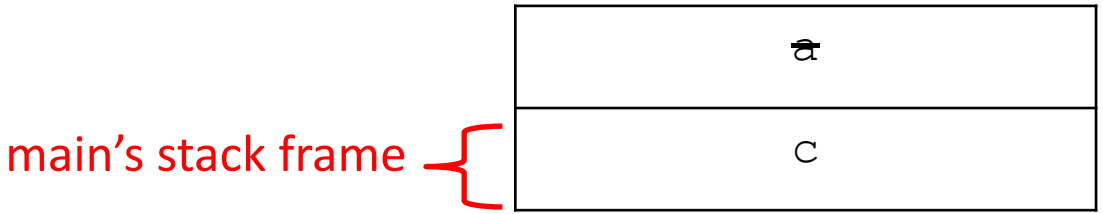
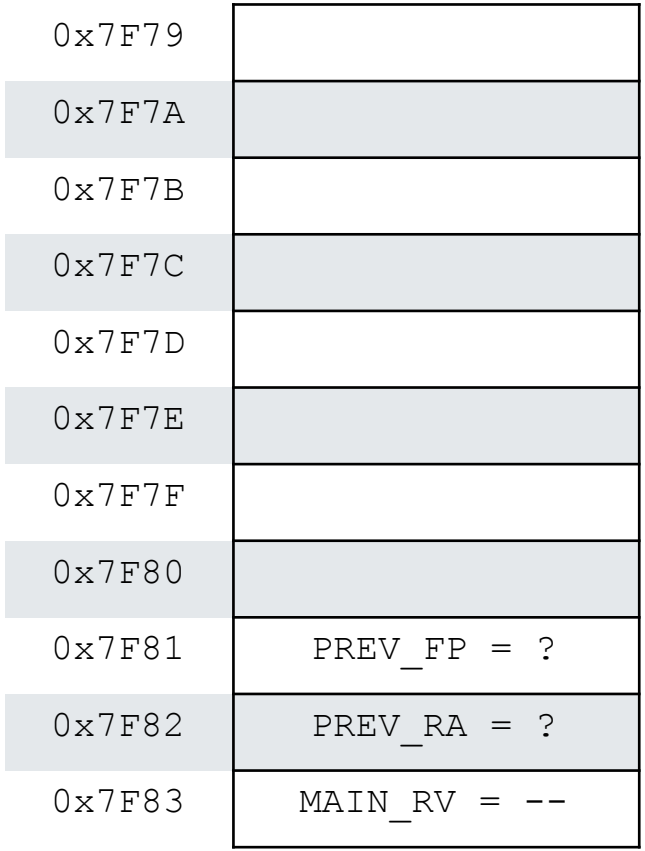


Some Acronyms

There are many things used to maintain the stack

- PC
  - The Program Counter. Keeps track of the next instruction to be executed
- SP
  - The Stack Pointer. Keeps track of the top of the stack (R6 in LC4)
- FP
  - The Frame Pointer. Keeps track of the bottom of the current stack frame. (R5 in LC4)
- RA
  - The Return Address. What to set the PC to when we return from the function so we can resume executing the calling function
- RV
  - The Return Value. The value returned from the function

The Call Stack: C Example (LC4 Details)

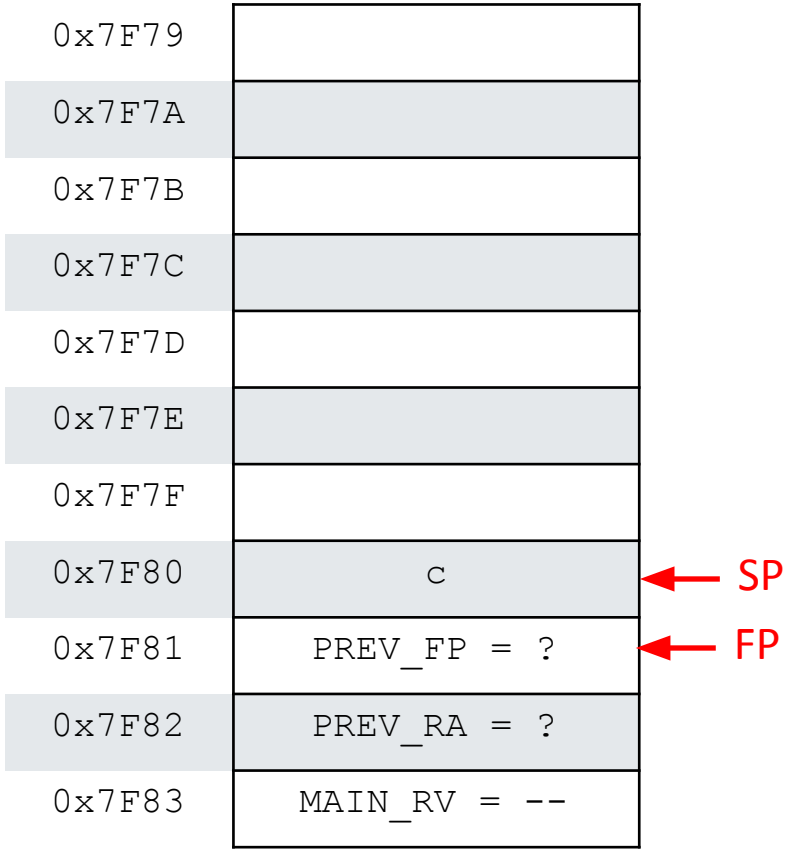



```
int foo() {
  int a;
  a = 3;
  return a;
}

int main() {
  int c;
  c = foo();
  return 0;
}
```

PC →

The Call Stack: C Example (LC4 Details)

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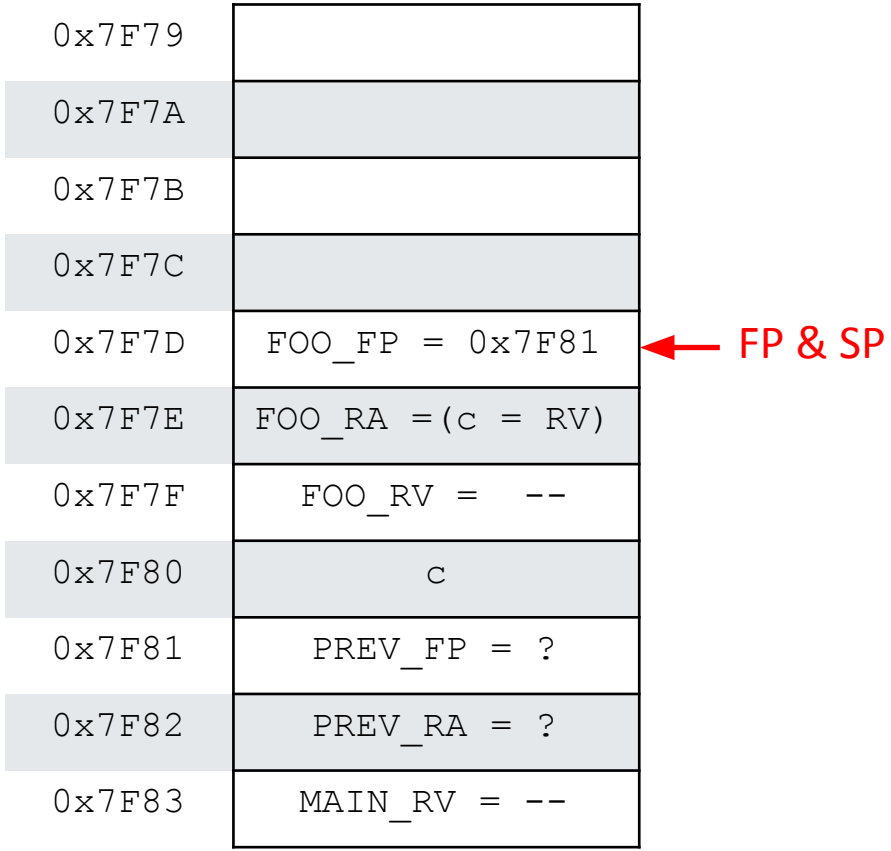

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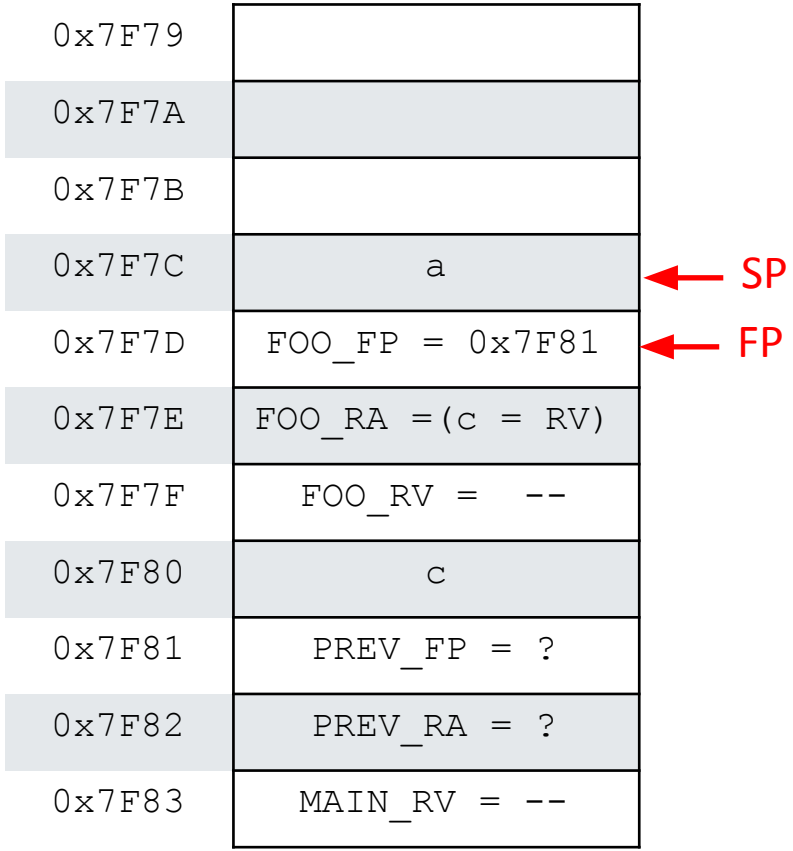

PC →

```
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}

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  int c;
  c = foo();
  return 0;
}
```
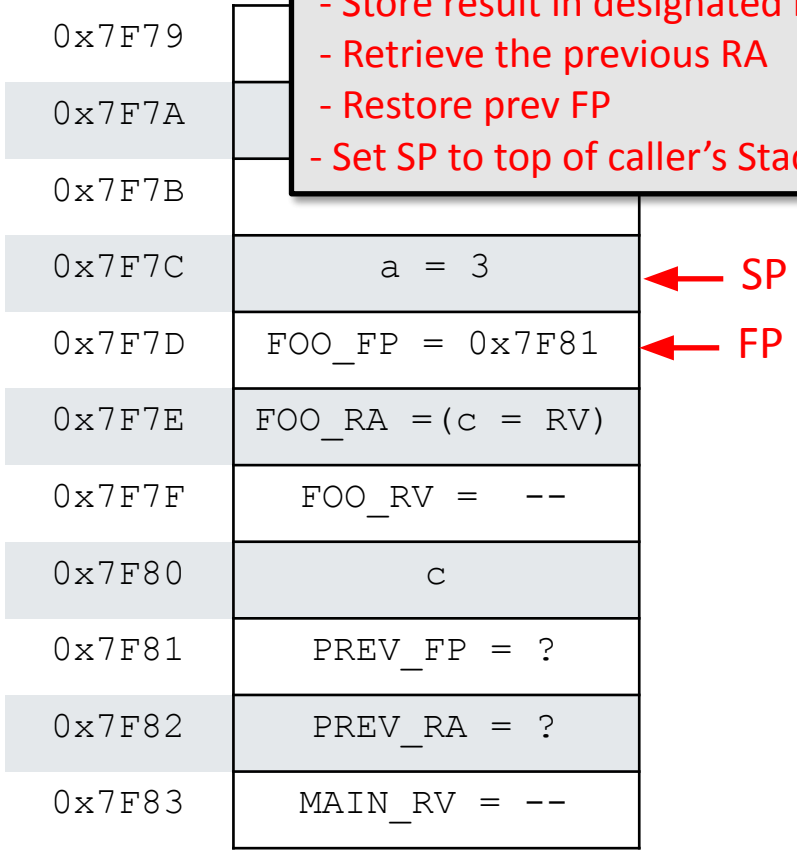

The Call Sta s)

To return, we need to:
- Store result in designated RV slot
- Retrieve the previous RA
- Restore prev FP
- Set SP to top of caller's Stack frame



PC →

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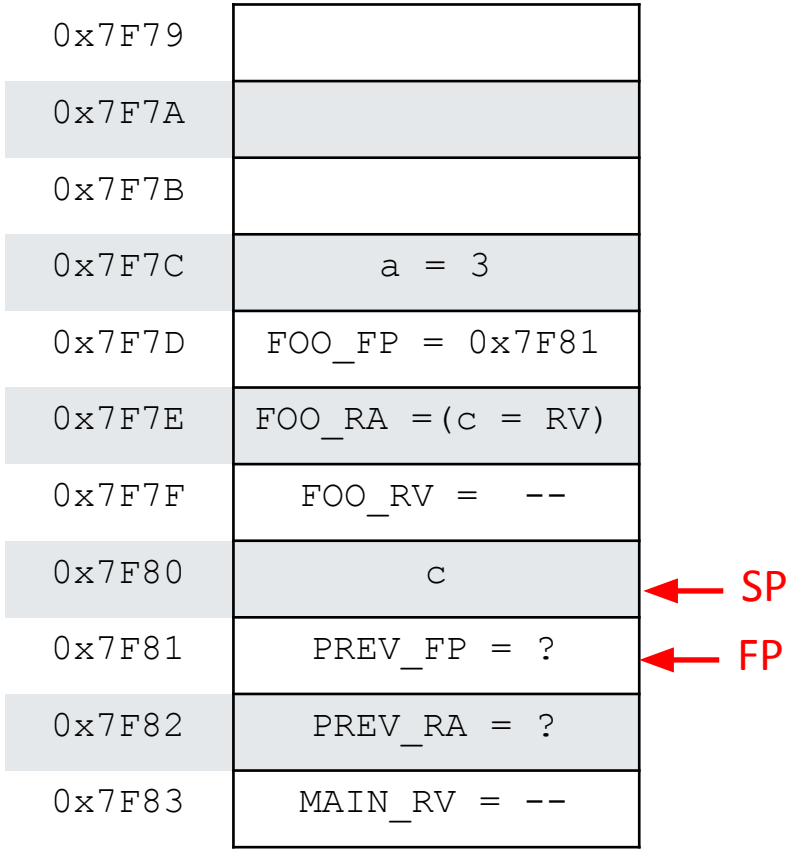
  c = foo();
  return 0;
}
```

The Call Stack: C Example (LC4 Details)

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PC →

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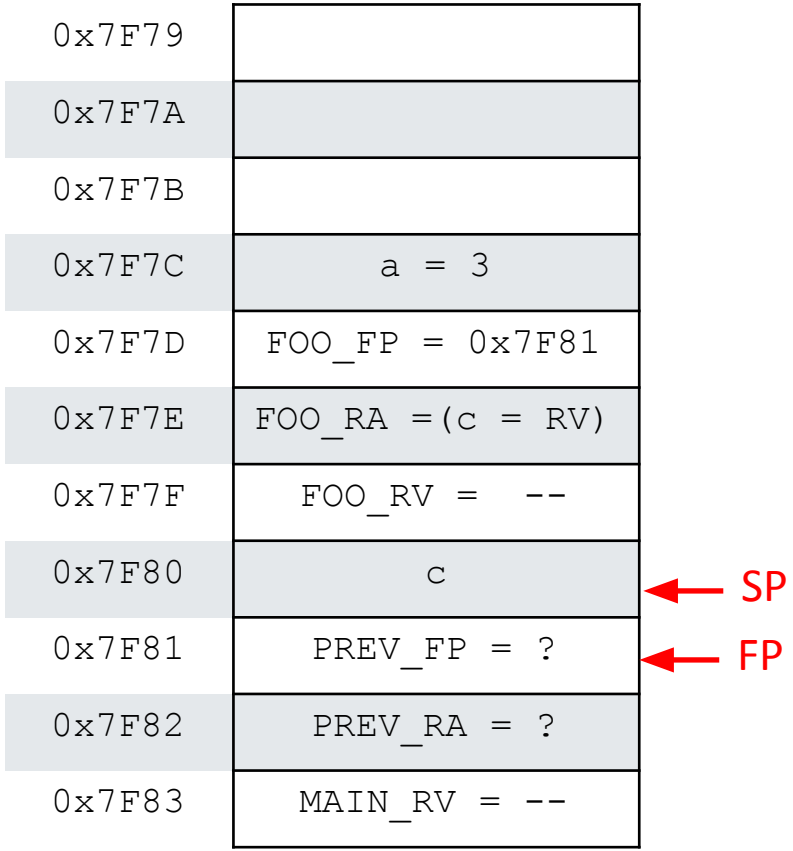


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```
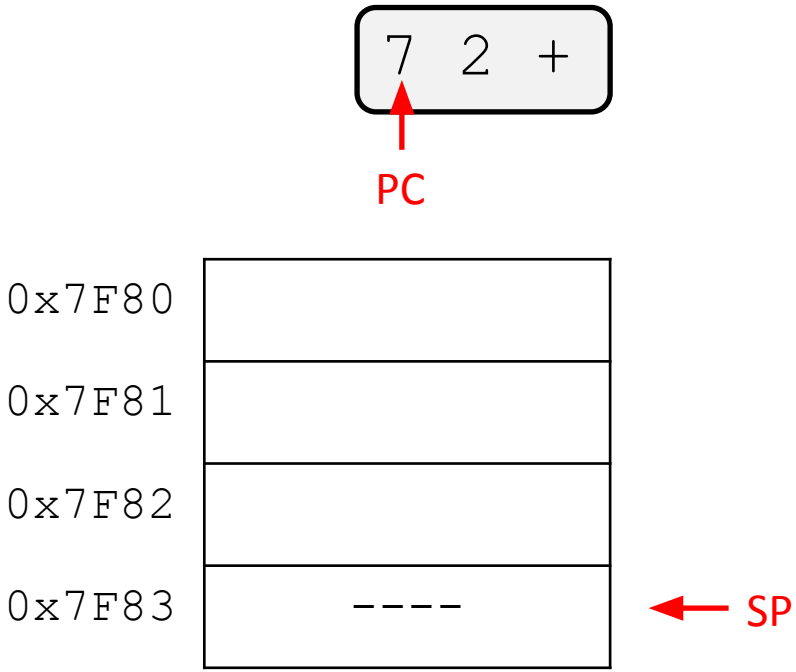

PC →

How Does This Apply To J?

We can't give all the details, but consider the following program:



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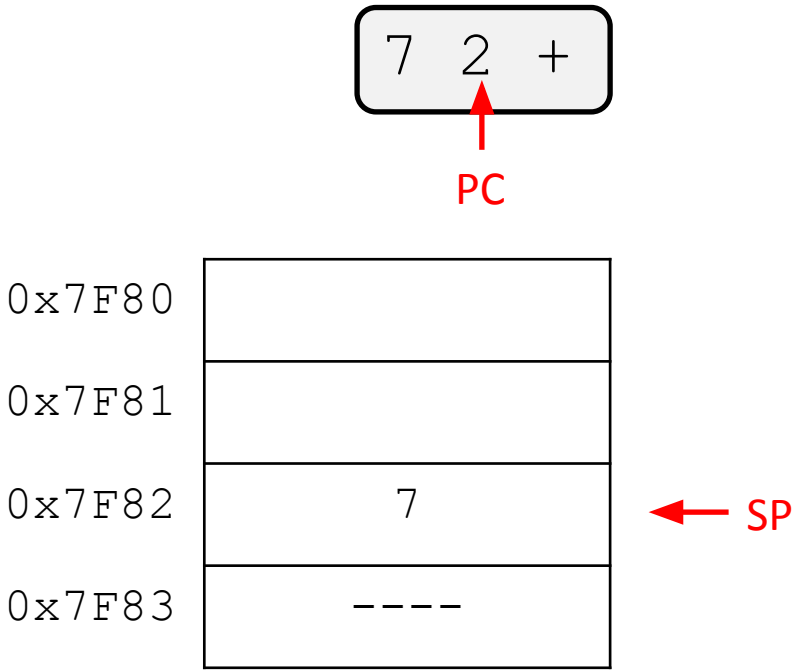

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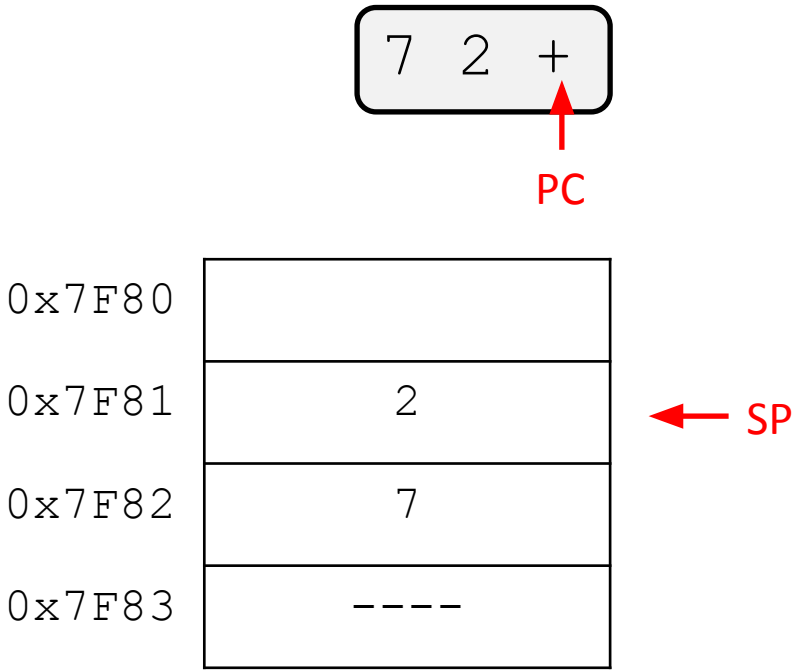

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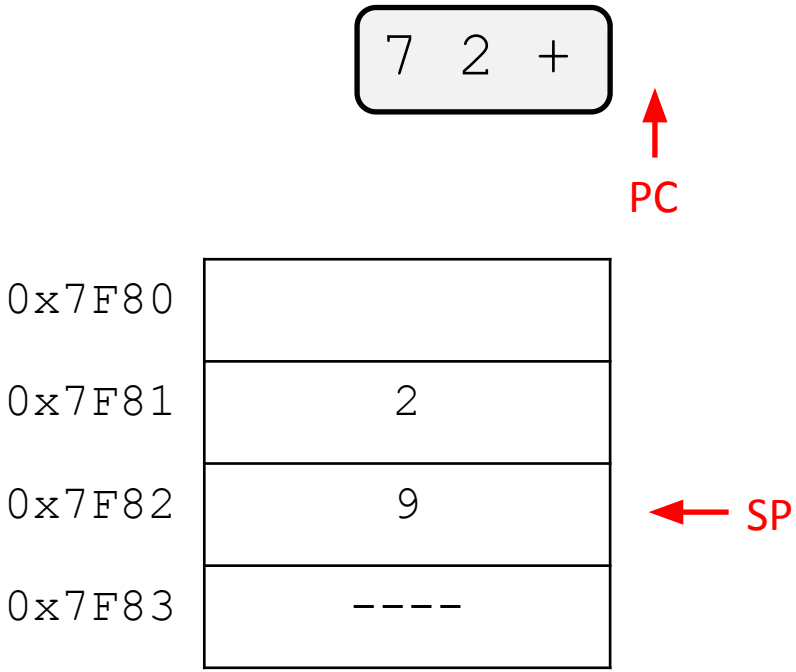

Assembler Directives

There are two assembler directives you will need for this assignment

- .CODE
  - Tells the assembler that we are about to start a new section of instruction code. Store this in the appropriate memory segment
- .FALIGN
  - Align the current address to the next multiple of 16.
  - Necessary for functions since functions must start at an offset that is a multiple of 16 for JSR to work

Tips

This didn't cover everything

This presentation is already probably too long…

Some difficulties you may need to figure out

- We didn't actually show any LC4 instructions, just high-level ideas
  - Look to lectures and old recitations for this
- Unique labels, nested if/else/endif, literals that need const & hiconst, etc.

Unique Labels

Remember, you cannot use offsets for JMP or BR instructions when writing LC4. You must use labels

You will need to use labels to implement IF/ELSE/ENDIF and WHILE

- What happens if you have many IF/ELSE/ENDIF blocks?
- Will need unique labels for each block
- Solution: Keep a counter and have the labels be variations of IF_1, ELSE_1, ENDIF_1, etc.

Nested If/Else/Endif

- What happens if there are many nested if/else/endifs?
- What if some of them are if/endifs?

```
2 3 4 - if - if 2 endif 1 else 0 endif
```

- There are two main approaches to handling this.
  - Using recursion
  - Using a stack data structure similar to HW6
    - **THIS IS NOT THE SAME AS THE CALL STACK IN LC4. THIS IS A C DATA STRUCTURE THAT WOULD BE USED IN YOUR CODE TO GENERATE THE LC4.**

Testing

- It is probably worth testing your `read_token` implementation (but not required)
- Write a short program that continuously reads tokens from a file and prints them out
- Test them on ALL provided test cases to make sure that it works

Testing

To test the program the final program, do the following

- Run your program on a .j file to create the corresponding .asm file
- Use PennSim to run the test case. Make sure you use the provided script and have the necessary files (e.g. os.asm)
- Check to see if the output is the same

Error Checking

- We will largely testing correct .j files
- It is still a good idea to add error checking to make sure you are handling things correctly
  - There shouldn't be a `defun` or `return` in the middle of an IF/ELSE/ENDIF block.
  - You shouldn't run into any BAD_TOKENS
  - The token after a `defun` *should* be an `ident` used for the function name

That's all we have for today!

Reminders:

- TA-lead recitations will take place on
  - Tuesdays 6:30-8:00pm in Moore 100A
  - Wednesday 12:00-1:30pm in Moore 100C
- HW10 is due 12/2 at 11:59pm (checkpoint for assignment)
- HW11 is due 12/9 at 11:59pm