# 15 – FUNCTIONS & PARAMETERS

COMP256 – COMPUTING ABSTRACTIONS

DICKINSON COLLEGE

## HLL FUNCTION CALL STACK 1

- The (function) **call stack** maintains the state of a running program.
- Each function call adds a **stack frame** to the call stack.
- A stack frame contains the:
  - Values of the **function's parameters (FP)**
  - **Return address (RA)**
  - Values of the function's **local variables (LV)**

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main() {
  read x;
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  m = max3(x,y,z);
  print m;
}
max3(a,b,c) {
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```

```
LV: Ø
RA: Exit
FP: Ø
```

main

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```

```
LV: x=3 y=7 z=4
RA: Exit
FP: Ø
```

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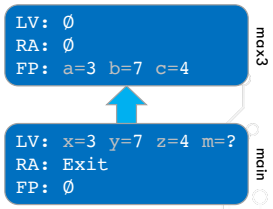


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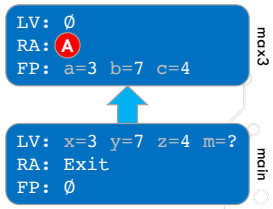


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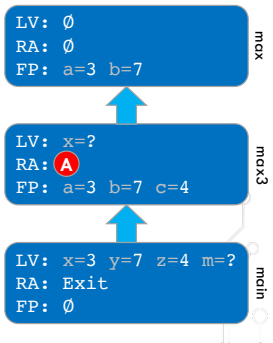


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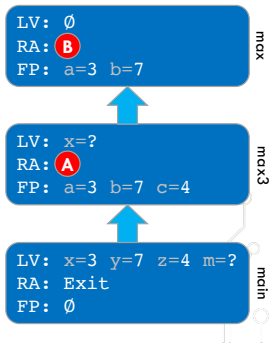

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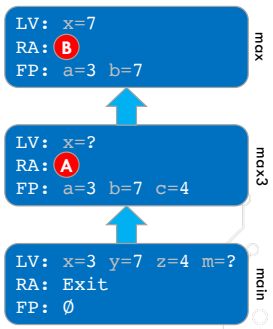


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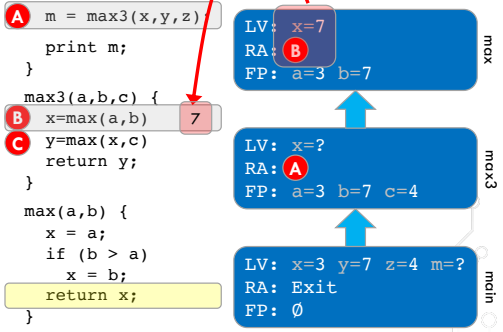
```

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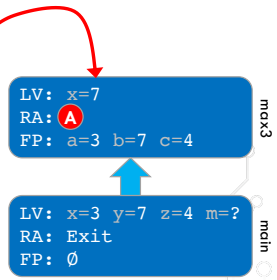


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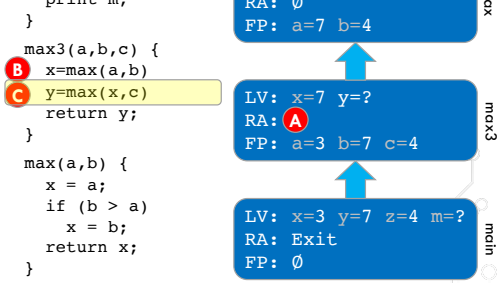

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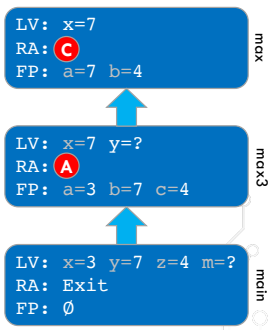


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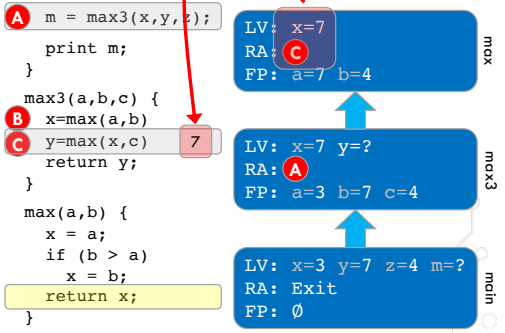


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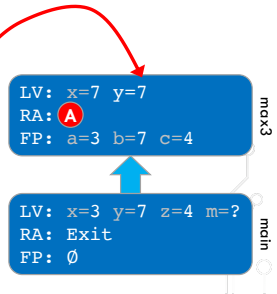


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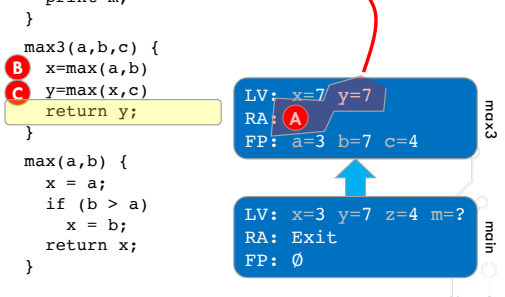

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```
LV: x=3 y=7 z=4 m=7
RA: Exit
FP: Ø
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```

7

```
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# UNPACKING THE FUNCTION CALL ABSTRACTION

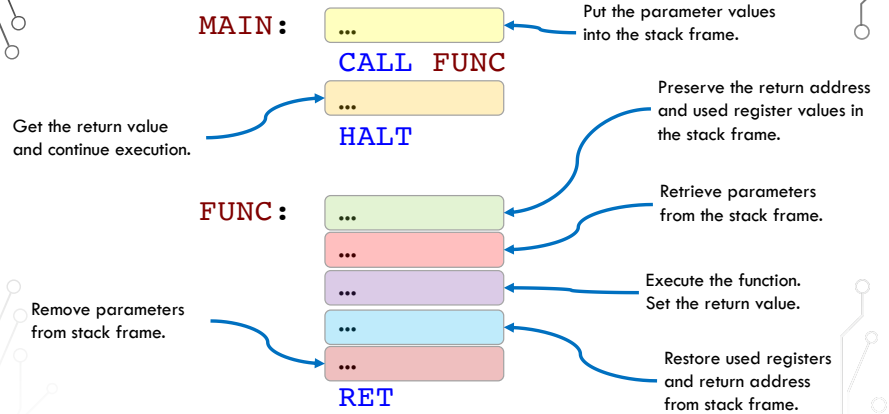
- Function calls in a high level language are an abstraction for the low level instructions in assembly/machine language that explicitly manage the stack frames.
  - These instructions:
    - Put parameter values into the stack frame
    - Call the function
    - Preserve the return address into the stack frame
    - **Preserve used register values in the stack frame**
    - Retrieve parameters from the stack frame
    - Execute the function
    - Set the return value
    - **Restore used register values from stack frame**
    - Restore the return address from stack frame
    - Remove parameters from stack frame
    - Return from the function
    - Get the return value and continue execution

Calling Code

Function Code

Calling Code

# FUNCTION CALLS IN ASSEMBLY



# CALLING AND RETURNING

| Instruction | Example | Meaning |
|---|---|---|
| CALL L | CALL FUNC | R12 = PC + 4, PC = FUNC |
| RET | RET | PC = R12 |

```
MAIN:   …
        CALL FUNC
        …
        HALT

FUNC:   …
        RET
```

R12 is a reserved register used for the return address of function calls.

# MANAGING STACK FRAMES

| Instruction | Example | Meaning |
|---|---|---|
| PUSH R | PUSH R2 | MM[R13] = R2; R13 = R13 - 4 |
| POP R | POP R2 | R13 = R13 + 4; R2 = MM[R13] |

```
.stacksize 100
LOAD R0 #10
PUSH R0
ADD R0 R0 #5
PUSH R0

POP R1
POP R2
```

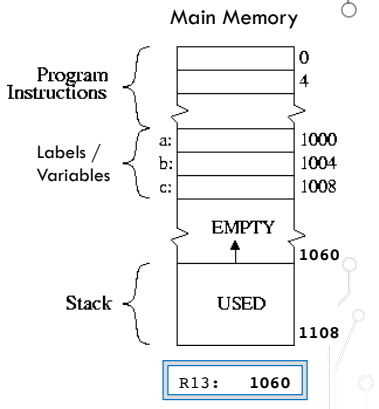
Set aside 100 bytes, enough for 25 pushes, for the function call stack and initialize R13.

R13 is a reserved register that holds the memory address for the next PUSH operation.

Register indirect addressing is used to access values in the stack frames.

# WHERE FOR ART THOU STACK?

- The `.stacksize` directive:
  - Sets aside the specified number of bytes to be used for the call stack.
  - Initializes the value of R13 to the address at which the next PUSH will occur.
    - Known as the *top of the stack*.




# GENERAL PURPOSE & RESERVED REGISTERS

- R0-R11: General purpose registers
  - Use them however you want in your programs.
- R12: The Return Address when a CALL is made
  - Set by CALL, used by RET
- R13: The Stack Pointer (address for the next PUSH)
  - Used by PUSH and POP
- R14: The Return Value from a function.
  - Functions will place their return value into R14, calling code will retrieve the return value from R14.
- R15: Scratch Register
  - Used by the assembler for intermediate results. Do not use.

## AN EXAMPLE

```
main() {
  read x;
  read y;

  m = max(x,y);

  print m;
}
```

```
max(a,b) {
  x = a;
  if (b > a)
    x = b;

  return x;
}
```

## MAIN FUNCTION

```
main() {
  read x;
  read y;

  m = max(x,y);

  print m;
}
```

```
X:      .word
Y:      .word
M:      .word

        * Allocate the call stack
        .stacksize 100  * 100 bytes/25 words

MAIN:   LOAD R0 STDIN   * read X
        STORE R0 X
        LOAD R1 STDIN   * read Y
        STORE R1 Y

        * Put parameters in stack frame for call
        PUSH R0         * X
        PUSH R1         * Y

        CALL MAX        * Transfer control to MAX

RA:     STORE R14 M     * Get the return value
        STORE R14 STDOUT

        HALT
```

## MAX FUNCTION

```
max(a,b) {
  x = a;
  if (b > a)
    x = b;

  return x;
}
```

```
MAX:    PUSH R12    * + 4
        PUSH R1     * + 8
        PUSH R2     * + 12
        PUSH R3     * + 16

        LOAD R2 R13 +20 * R2 is b
        LOAD R1 R13 +24 * R1 is a

        MOV R3 R1       * R3 is x = a

        BGEQ R1 R2 SKIP * a >= b
        MOV R3 R2       * x = b

SKIP:   MOV R14 R3      * RV = x

        POP R3
        POP R2
        POP R1
        POP R12

        ADD R13 R13 #8

        RET
```