CS41B RECURSION

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CS 52 – Fall 2015

Admin

Midterm back on Thursday

Assignments

- Assignment 4: due Monday (10/12 at 11:59pm)
- Assignment 5: due Friday (10/23 at 5pm)
- Assignment 6: due Monday (11/2 at 11:59pm)

Survey in assignment 4

Academic Honesty

Academic Honesty

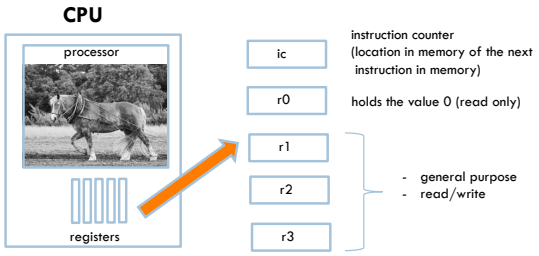
A few rules to follow for this course to keep you out of trouble:

- If you talk with someone in the class about a problem, you should not take notes. If you understand the material you talked about, you should be able to recreate it on your own.
- Similarly, if you talk with someone, you must wait 5 minutes before resuming work on the problem. Stretch. Use the restroom. Go for a quick walk. This will ensure that you really understand the material.
- You may not sit next to (or where you can see the screen of) anyone you are talking with about the assignment.
- The only time you may look at someone else's screen is if they are asking you for help with a basic programming problem (e.g. syntax error). You should not look at someone else's code to help yourself!

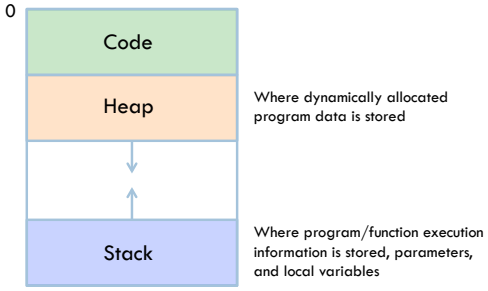
Examples from this lecture

http://www.cs.pomona.edu/~dkauchak/classes/cs52/examples/cs41b/

CS41B machine



Memory layout



Stack frame

Key unit for keeping track of a function call

- return address (where to go when we're done executing)
- parameters
- local variables

CS41B function call conventions

r1: reserved for the stack pointer

r2: contains the return address

r3: contains the first parameter

additional parameters go on the stack (more on this)

the result (i.e. the return value) should go in r3

Structure of a single parameter function

```
fname
      psh r2              ; save return address on stack
      ...                 ; do work using r3 as argument
                          ; put result in r3
      pop r2              ; restore return address from stack
      jmp r2              ; return to caller
```

conventions:
- argument is in r3
- r1 is off-limits since it's used for the stack pointer
- return value goes in r3

Our first function call

```
    loa r3 r0         ; get variable

    lcw r2 increment  ; call increment
    cal r2 r2

    sto r0 r3         ; write result,
    hlt               ;    and halt

increment
    psh r2            ; save the return address on the stack
    adc r3 r3 1       ; add 1 to the input parameter
    pop r2            ; get the return address from stack
    jmp r2            ; go back to where we were called from
```

Functions with multiple arguments

```
fname
      psh r2              ; save return address on stack
      loa r2 r1 4         ; load the second parameter into r2
      ...                 ; do work using r3 and r2 as arguments
                          ; put result in r3
      pop r2              ; restore return address from stack
      jmp r2              ; return to caller
```

conventions:
- first argument is in r3
- r1 is off-limits since it's used for the stack pointer
- return value goes in r3

Functions with multiple arguments

```
fname
      psh r2              ; save return address on stack
      loa r2 r1 4         ; load the second parameter into r2
      ...                 ; do work using r3 and r2 as arguments
                          ; put result in r3
      pop r2              ; restore return address from stack
      jmp r2              ; return to caller
```

loa	RR[S]	dest = mem[src0 + arg]

What does this operation do? What is the 4?

Functions with multiple arguments

```
fname
      psh r2              ; save return address on stack
      loa r2 r1 4         ; load the second parameter into r2
      ...                 ; do work using r3 and r2 as arguments
                          ; put result in r3
      pop r2              ; restore return address from stack
      jmp r2              ; return to caller
```

loa	RR[S]	dest = mem[src0 + arg]

- r1 is the stack pointer and points at the top (next) slot
- stacks grow towards smaller memory values

Functions with multiple arguments

```
fname
      psh r2              ; save return address on stack
      loa r2 r1 4         ; load the second parameter into r2
      ...                 ; do work using r3 and r2 as arguments
                          ; put result in r3
      pop r2              ; restore return address from stack
      jmp r2              ; return to caller
```

loa	RR[S]	dest = mem[src0 + arg]

- r1 is the stack pointer and points at the top (next) slot
- stacks grow towards smaller memory values
- r1+2 is then the top value of the stack
- r1+4 is the 2nd value of the stack

Multiple arguments

```
max
      psh r2
      loa r2 r1 4

      bge r3 r2 endif
      adc r3 r2 0
endif
      pop r2
      jmp r2
```

What does this code do?

Multiple arguments

```
max
      psh r2
      loa r2 r1 4

      bge r3 r2 endif
      adc r3 r2 0
endif
      pop r2
      jmp r2
```

max, as a function!

Calling max

```
    loa r3 r0
    loa r2 r0

    psh r2
    lcw r2 max
    cal r2 r2
    pop r2

    sto r0 r3
    hlt
```

Anything different?

Calling max

```
    loa r3 r0
    loa r2 r0

    psh r2
    lcw r2 max
    cal r2 r2
    pop r2

    sto r0 r3
    hlt
```

For the second argument, push it on the stack

```
    loa r3 r0
    loa r2 r0

    psh r2
    lcw r2 max
    cal r2 r2
    pop r2

    sto r0 r3
    hlt
max
    psh r2
    loa r2 r1 4

    bge r3 r2 endif
    adc r3 r2 0
endif
    pop r2
    jmp r2
```


```
    loa r3 r0
    loa r2 r0

    psh r2
    lcw r2 max
    cal r2 r2
    pop r2

    sto r0 r3
    hlt
max
    psh r2
    loa r2 r1 4

    bge r3 r2 endif
    adc r3 r2 0
endif
    pop r2
    jmp r2
```

```
    loa r3 r0
    loa r2 r0

    psh r2
    lcw r2 max
    cal r2 r2
    pop r2

    sto r0 r3
    hlt
max
    psh r2
    loa r2 r1 4

    bge r3 r2 endif
    adc r3 r2 0
endif
    pop r2
    jmp r2
```

r2	2
r3	10

sp (r1) ←

Stack

```
    loa r3 r0
    loa r2 r0

    psh r2
    lcw r2 max
    cal r2 r2
    pop r2

    sto r0 r3
    hlt
max
    psh r2
    loa r2 r1 4

    bge r3 r2 endif
    adc r3 r2 0
endif
    pop r2
    jmp r2
```

r2	2
r3	10

sp (r1) ←

2

Stack

```
    loa r3 r0
    loa r2 r0

    psh r2
    lcw r2 max
    cal r2 r2
    pop r2

    sto r0 r3
    hlt
max
    psh r2
    loa r2 r1 4

    bge r3 r2 endif
    adc r3 r2 0
endif
    pop r2
    jmp r2
```

r2	2
r3	10

sp (r1) ←

2

Stack

```
    loa r3 r0
    loa r2 r0

    psh r2
    lcw r2 max
    cal r2 r2
    pop r2

    sto r0 r3
    hlt
max
    psh r2
    loa r2 r1 4

    bge r3 r2 endif
    adc r3 r2 0
endif
    pop r2
    jmp r2
```

r2	max
r3	10

Notice that we overwrote the value in r2

If we hadn't save it on the stack, it would have been lost

sp (r1) ←

2

Stack

```
    loa r3 r0
    loa r2 r0

    psh r2
    lcw r2 max
    cal r2 r2
    pop r2

    sto r0 r3
    hlt
max
    psh r2
    loa r2 r1 4

    bge r3 r2 endif
    adc r3 r2 0
endif
    pop r2
    jmp r2
```

r2	max
r3	10

sp (r1) ←

2

Stack

```
    loa r3 r0
    loa r2 r0

    psh r2
    lcw r2 max
    cal r2 r2
    pop r2

    sto r0 r3
    hlt
max
    psh r2
    loa r2 r1 4

    bge r3 r2 endif
    adc r3 r2 0
endif
    pop r2
    jmp r2
```

r2	loc: cal
r3	10

sp (r1) ←

2

Stack

```
    loa r3 r0
    loa r2 r0

    psh r2
    lcw r2 max
    cal r2 r2
    pop r2

    sto r0 r3
    hlt
max
    psh r2
    loa r2 r1 4

    bge r3 r2 endif
    adc r3 r2 0
endif
    pop r2
    jmp r2
```

r2	loc: cal
r3	10

sp (r1) ←

2

Stack

```
    loa r3 r0
    loa r2 r0

    psh r2
    lcw r2 max
    cal r2 r2
    pop r2

    sto r0 r3
    hlt
max
    psh r2
    loa r2 r1 4

    bge r3 r2 endif
    adc r3 r2 0
endif
    pop r2
    jmp r2
```

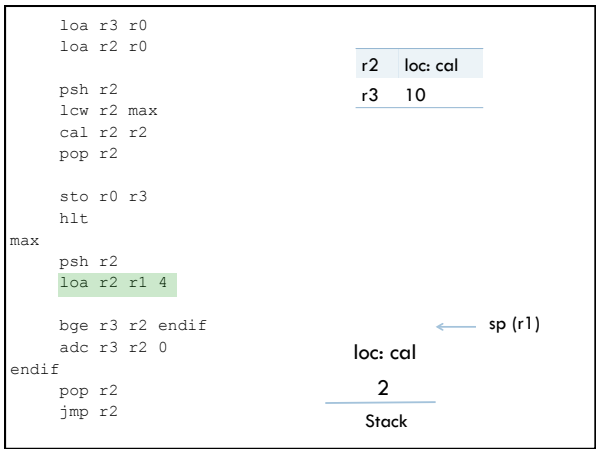
r2	loc: cal
r3	10

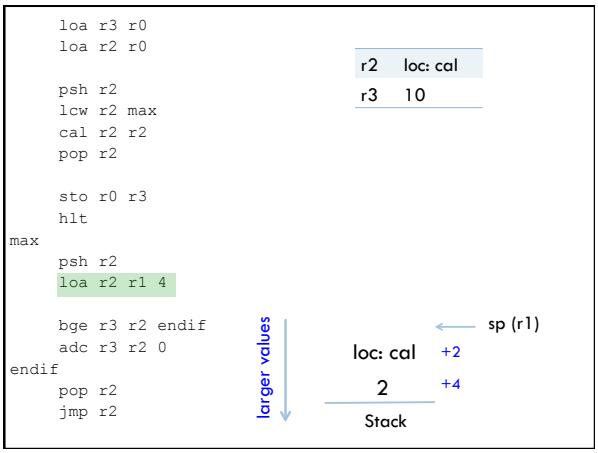
sp (r1) ←

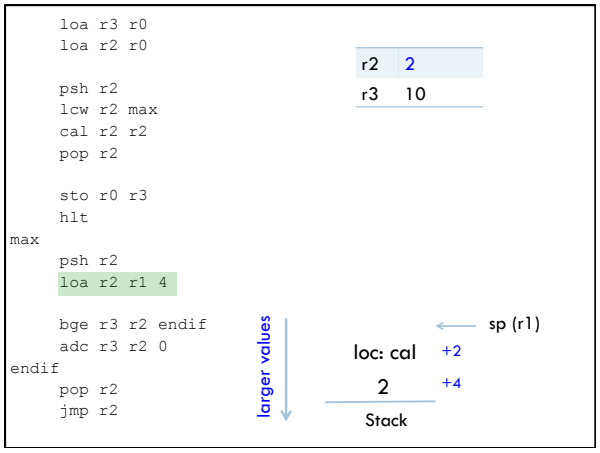
loc: cal

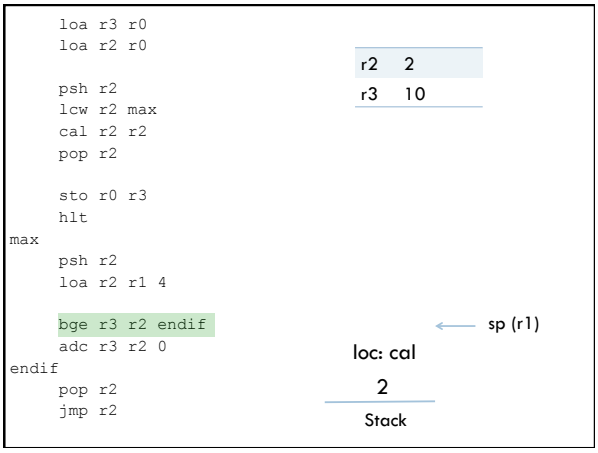
2

Stack


loa r3 r0
loa r2 r0
psh r2
lcw r2 max
cal r2 r2
pop r2
sto r0 r3
hlt
max
psh r2
loa r2 r1 4
bge r3 r2 endif
adc r3 r2 0
endif
pop r2
jmp r2
r2 loc: cal
r3 10
sp (r1)
loc: cal
2
Stack


loa r3 r0
loa r2 r0
psh r2
lcw r2 max
cal r2 r2
pop r2
sto r0 r3
hlt
max
psh r2
loa r2 r1 4
bge r3 r2 endif
adc r3 r2 0
endif
pop r2
jmp r2
larger values
r2 loc: cal
r3 10
sp (r1)
loc: cal +2
2 +4
Stack


loa r3 r0
loa r2 r0
psh r2
lcw r2 max
cal r2 r2
pop r2
sto r0 r3
hlt
max
psh r2
loa r2 r1 4
bge r3 r2 endif
adc r3 r2 0
endif
pop r2
jmp r2
larger values
r2 2
r3 10
sp (r1)
loc: cal +2
2 +4
Stack


loa r3 r0
loa r2 r0
psh r2
lcw r2 max
cal r2 r2
pop r2
sto r0 r3
hlt
max
psh r2
loa r2 r1 4
bge r3 r2 endif
adc r3 r2 0
endif
pop r2
jmp r2
r2 2
r3 10
sp (r1)
loc: cal
2
Stack

```
     loa r3 r0
     loa r2 r0

     psh r2
     lcw r2 max
     cal r2 r2
     pop r2

     sto r0 r3
     hlt
max
     psh r2
     loa r2 r1 4

     bge r3 r2 endif
     adc r3 r2 0
endif
     pop r2
     jmp r2
```

r2	2
r3	10

sp (r1)

loc: cal

2

Stack

```
     loa r3 r0
     loa r2 r0

     psh r2
     lcw r2 max
     cal r2 r2
     pop r2

     sto r0 r3
     hlt
max
     psh r2
     loa r2 r1 4

     bge r3 r2 endif
     adc r3 r2 0
endif
     pop r2
     jmp r2
```

r2	loc: cal
r3	10

sp (r1)

2

Stack

```
     loa r3 r0
     loa r2 r0

     psh r2
     lcw r2 max
     cal r2 r2
     pop r2

     sto r0 r3
     hlt
max
     psh r2
     loa r2 r1 4

     bge r3 r2 endif
     adc r3 r2 0
endif
     pop r2
     jmp r2
```

r2	loc: cal
r3	10

sp (r1)

2

Stack

```
     loa r3 r0
     loa r2 r0

     psh r2
     lcw r2 max
     cal r2 r2
     pop r2

     sto r0 r3
     hlt
max
     psh r2
     loa r2 r1 4

     bge r3 r2 endif
     adc r3 r2 0
endif
     pop r2
     jmp r2
```

r2	loc: cal
r3	10

sp (r1)

2

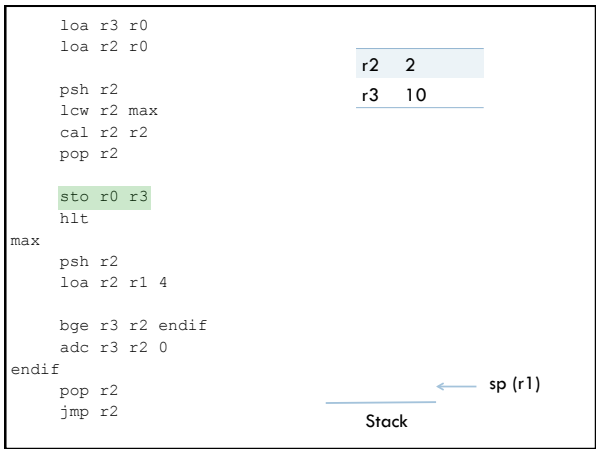
Stack

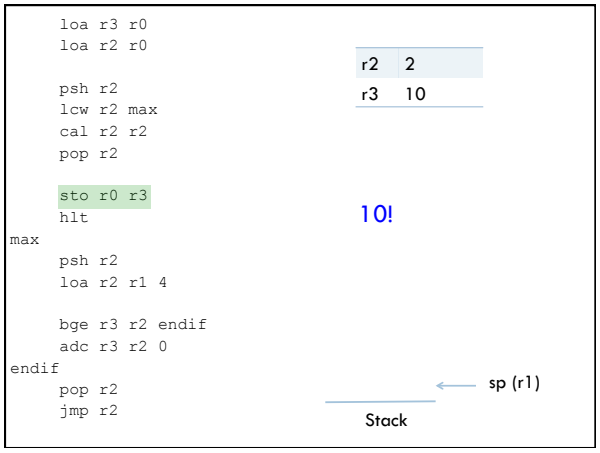
```
     loa r3 r0
     loa r2 r0

     psh r2
     lcw r2 max
     cal r2 r2
     pop r2

     sto r0 r3
     hlt
max
     psh r2
     loa r2 r1 4

     bge r3 r2 endif
     adc r3 r2 0
endif
     pop r2
     jmp r2
```

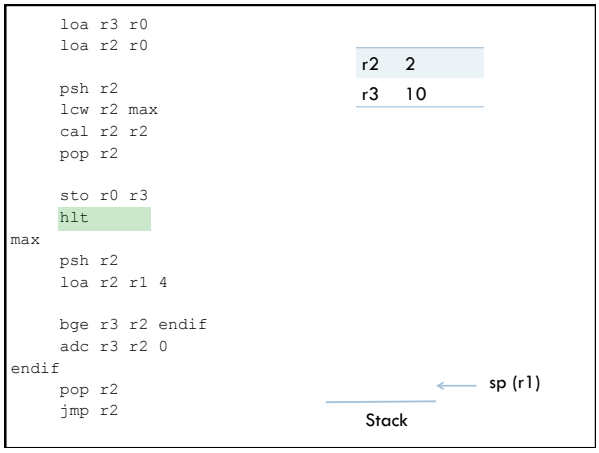
r2	2
r3	10

← sp (r1)

Stack







Real structure of CS41B program

```
; great comments at the top!
;
        lcw r1 stack

        instruction1        ; comment
        instruction2        ; comment
        ...
        hlt

;
; stack area: 50 words
;
         dat 100
stack
        end
```

Save address of highest end (highest address) of the stack in r1

Reserve 50 words for the stack

Recursion

```
int mystery(int a, int b){
   if( b <= 0 ){
     return 0
   else
     return a + mystery(a, b-1)
   }
}
```

What does this function do?

Recursion

```
int mystery(int a, int b){
   if( b <= 0 ){
     return 0
   else
     return a + mystery(a, b-1)
   }
}
```

Multiplication… a*b (assuming b is positive)

Note to future Dave from past Dave: write the function up on the board ☺

```
mult
      psh r2          ; save the return address
      psh r3          ; save first argument, a, on stack
      loa r2 r1 6     ; get at the 2nd argument, b
                      ; b = r2, a = r3

      blt r0 r2 else  ; 0 < r2, i.e. recursive case
      adc r3 r0 0     ; return 0
      brs endif
else
      sbc r2 r2 1     ; r2 = b-1
      psh r2          ; add r2 as 2nd argument

      lcw r2 mult     ; call mult recursively
      cal r2 r2
      pop r2          ; pop 2nd argument off stack

      loa r2 r1 2     ; load a into r2 off of the stack
      add r3 r3 r2    ; r3 = a + mult(a, b-1)
endif
      pop r0          ; remove first argument from stack
      pop r2          ; get the return address
      jmp r2          ; return
```

Function startup

Base case

Recursive case

Recursive call

answer calculation

Function cleanup and return

```
mult
    psh r2          ; save the return address
    psh r3          ; save first argument, a, on stack
    loa r2 r1 6     ; get at the 2nd argument, b
                    ; b = r2, a = r3

    blt r0 r2 else  ; 0 < r2, i.e. recursive case
    adc r3 r0 0     ; return 0
    brs endif
else
    sbc r2 r2 1     ; r2 = b-1
    psh r2          ; add r2 as 2nd argument, r3 shouldn't have changed

    lcw r2 mult     ; call mult recursively
    cal r2 r2
    pop r2          ; pop 2nd argument off stack

    loa r2 r1 2     ; load a into r2 off of the stack
    add r3 r3 r2    ; r3 = a + mult(a, b-1)
endif
    pop r0          ; remove first argument from stack
    pop r2          ; get the return address
    jmp r2          ; return
```

Notice symmetry of psh and pop

Calling mult

```
loa r3 r0
loa r2 r0

psh r2
lcw r2 mult
cal r2 r2

pop r2

sto r0 r3
hlt
```

r2

r3

← sp (r1)

Stack

Calling mult

```
loa r3 r0
loa r2 r0

psh r2
lcw r2 mult
cal r2 r2

pop r2

sto r0 r3
hlt
```

r2

r3

← sp (r1)

Stack

Calling mult

```
loa r3 r0
loa r2 r0

psh r2
lcw r2 mult
cal r2 r2

pop r2

sto r0 r3
hlt
```

r2

r3 6

← sp (r1)

Stack

Calling mult

```
loa r3 r0
loa r2 r0

psh r2
lcw r2 mult
cal r2 r2

pop r2

sto r0 r3
hlt
```

r2	
r3	6

sp (r1)

Stack

Calling mult

```
loa r3 r0
loa r2 r0

psh r2
lcw r2 mult
cal r2 r2

pop r2

sto r0 r3
hlt
```

r2	2
r3	6

sp (r1)

Stack

Calling mult

```
loa r3 r0
loa r2 r0

psh r2
lcw r2 mult
cal r2 r2

pop r2

sto r0 r3
hlt
```

r2	2
r3	6

sp (r1)

Stack

Calling mult

```
loa r3 r0
loa r2 r0

psh r2
lcw r2 mult
cal r2 r2

pop r2

sto r0 r3
hlt
```

r2	2
r3	6

sp (r1)

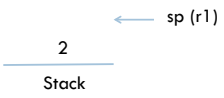
2

Stack

Calling mult

```
loa r3 r0
loa r2 r0

psh r2
lcw r2 mult
cal r2 r2

pop r2

sto r0 r3
hlt
```

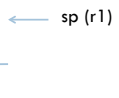
r2	2
r3	6



Calling mult

```
loa r3 r0
loa r2 r0

psh r2
lcw r2 mult
cal r2 r2

pop r2

sto r0 r3
hlt
```

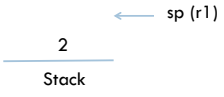
r2	loc: mult
r3	6



Calling mult

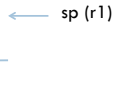
```
loa r3 r0
loa r2 r0

psh r2
lcw r2 mult
cal r2 r2

pop r2

sto r0 r3
hlt
```

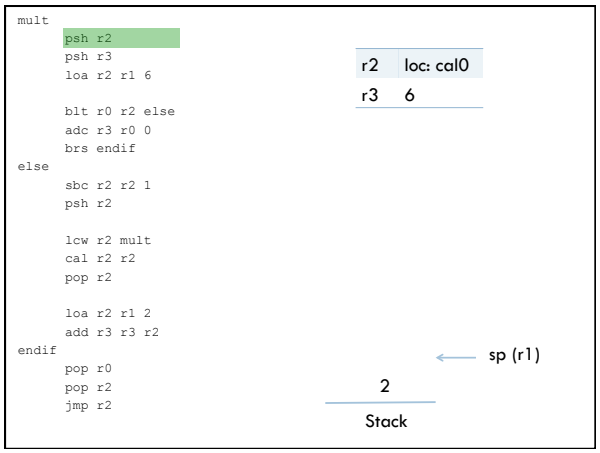
r2	loc: mult
r3	6

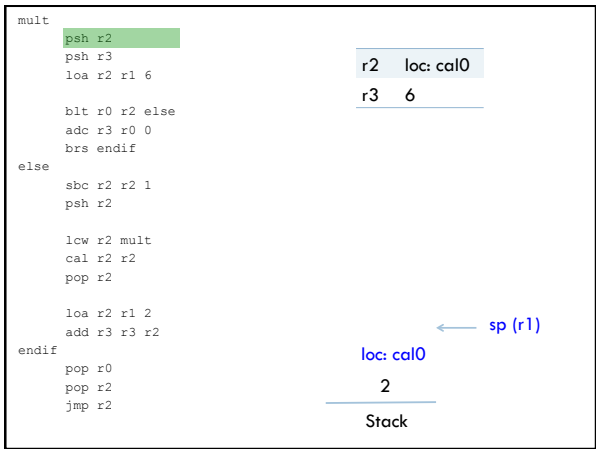


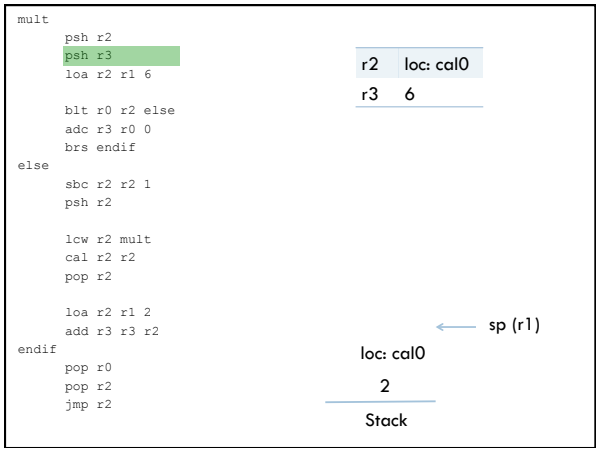

```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1
      psh r2

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

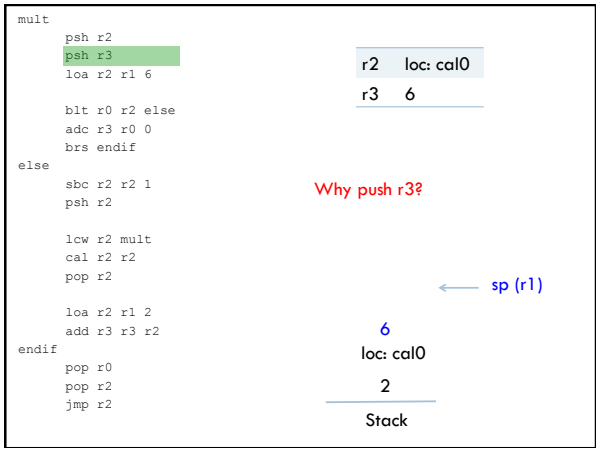
r2	loc: cal0
r3	6

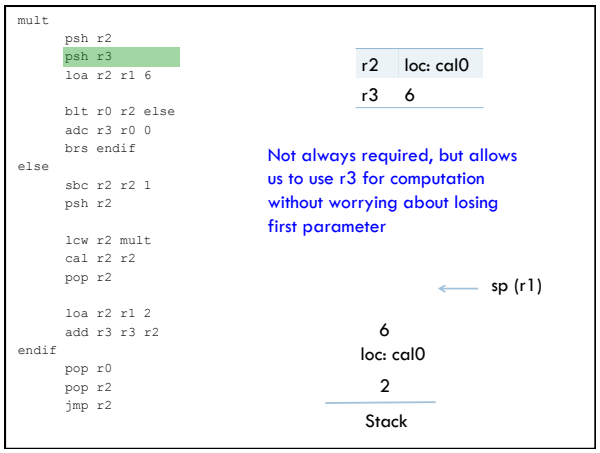


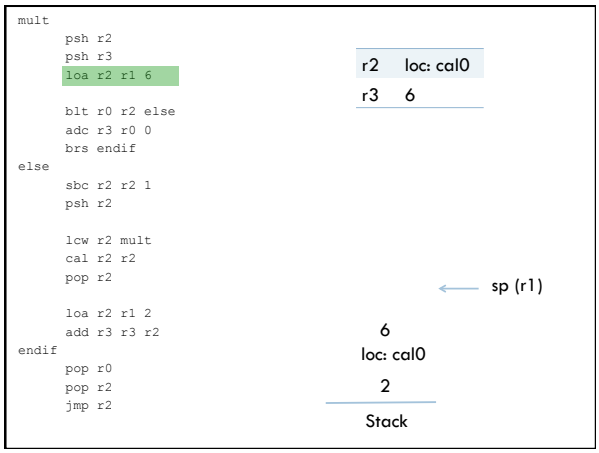

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal0
r3 6
sp (r1)
2
Stack

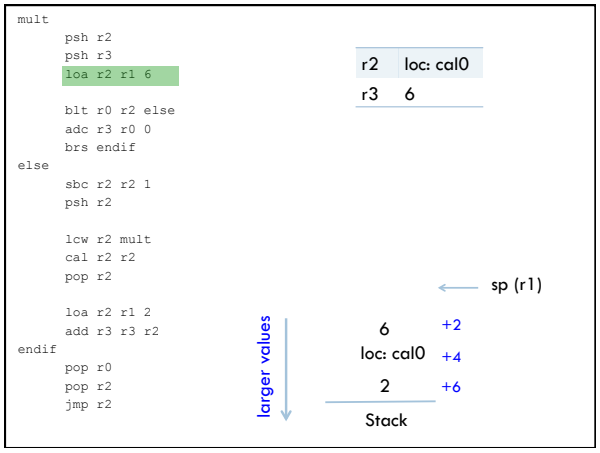

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal0
r3 6
sp (r1)
loc: cal0
2
Stack

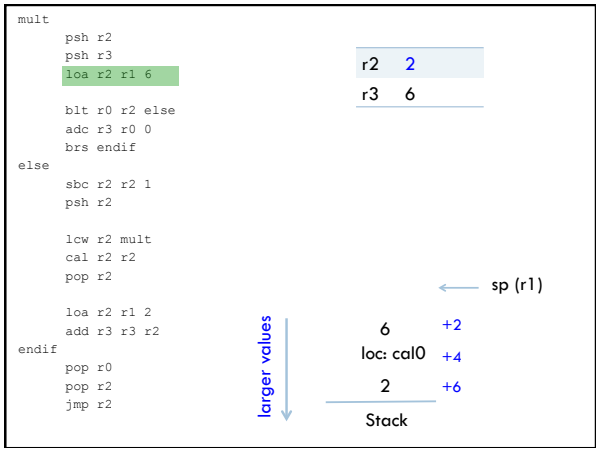

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal0
r3 6
sp (r1)
loc: cal0
2
Stack

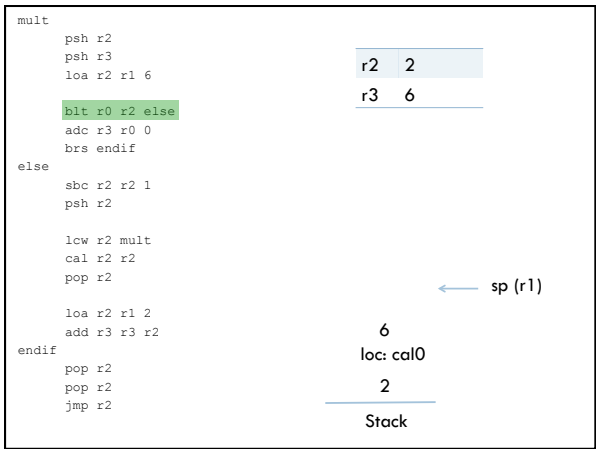

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal0
r3 6
Why push r3?
sp (r1)
6
loc: cal0
2
Stack

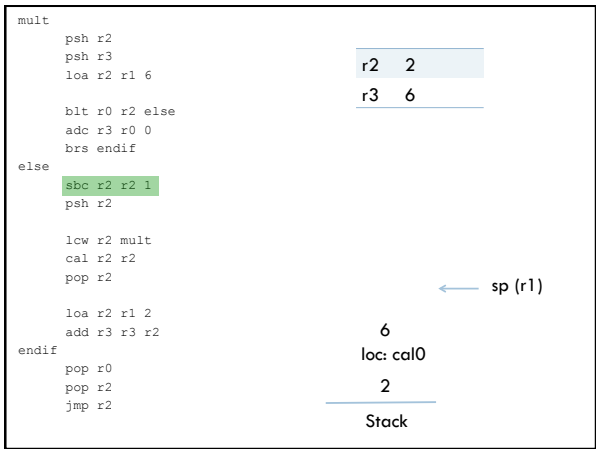

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal0
r3 6
Not always required, but allows us to use r3 for computation without worrying about losing first parameter
sp (r1)
6
loc: cal0
2
Stack

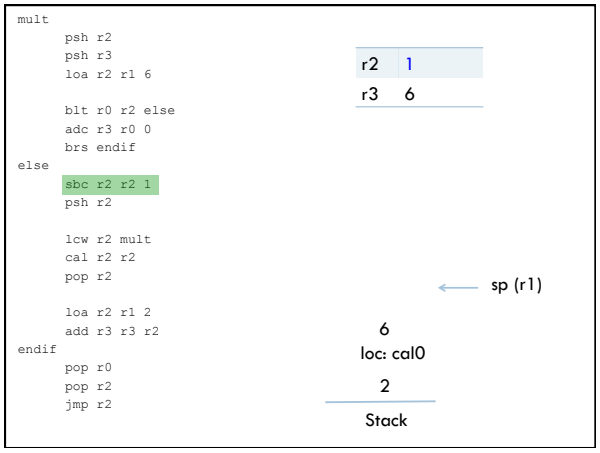

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal0
r3 6
sp (r1)
6
loc: cal0
2
Stack

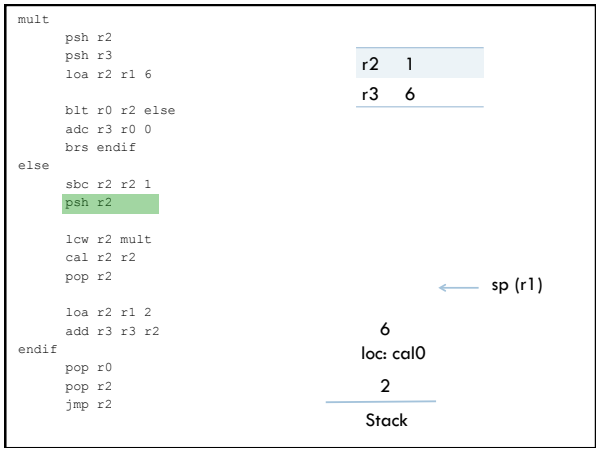

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal0
r3 6
sp (r1)
larger values
6 +2
loc: cal0 +4
2 +6
Stack

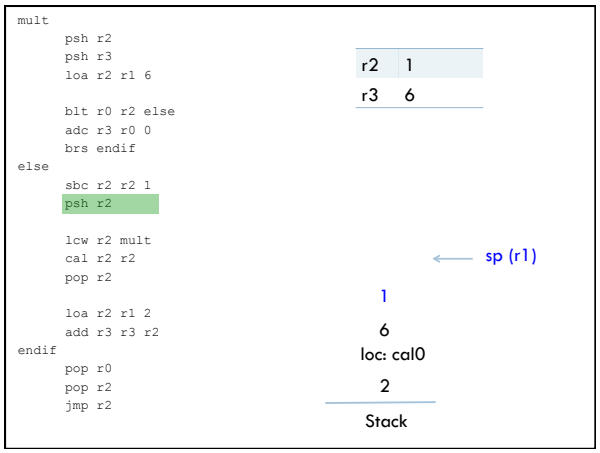

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 2
r3 6
sp (r1)
larger values
6 +2
loc: cal0 +4
2 +6
Stack

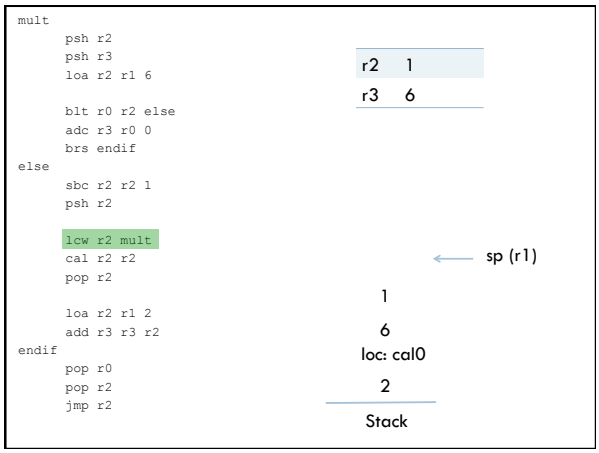

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r2
pop r2
jmp r2
r2 2
r3 6
sp (r1)
6
loc: cal0
2
Stack

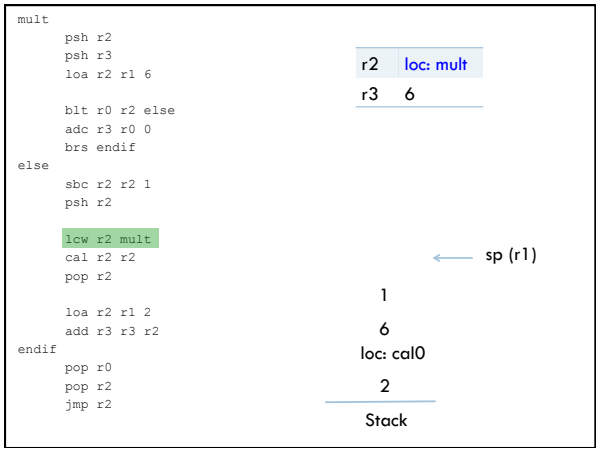

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 2
r3 6
sp (r1)
6
loc: cal0
2
Stack

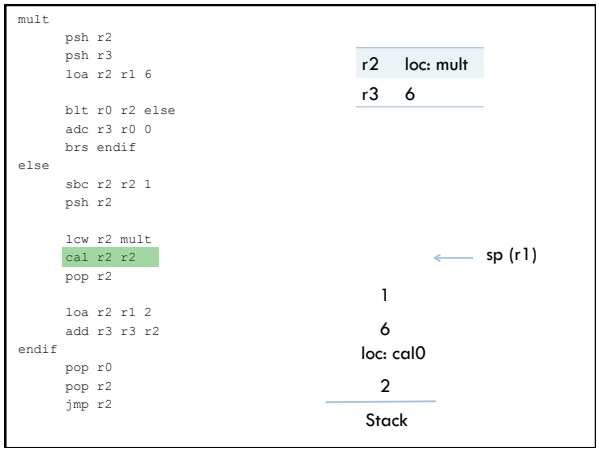

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 1
r3 6
sp (r1)
6
loc: cal0
2
Stack

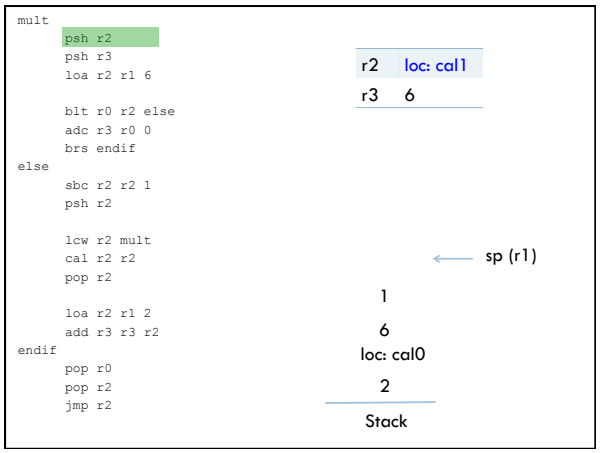

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 1
r3 6
sp (r1)
6
loc: cal0
2
Stack

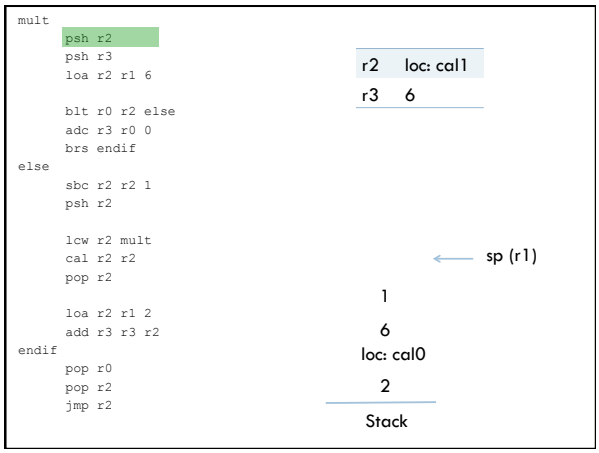

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 1
r3 6
sp (r1)
1
6
loc: cal0
2
Stack

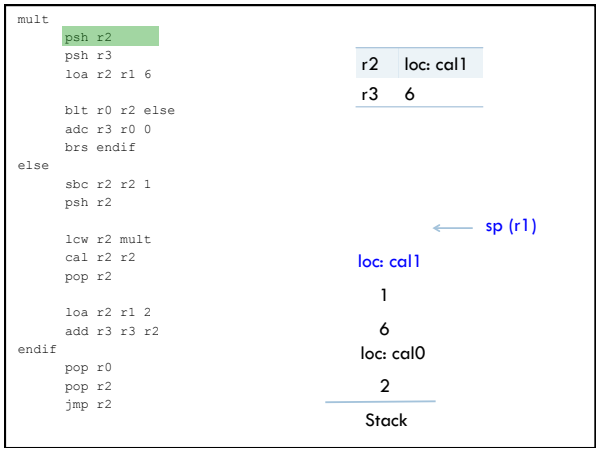

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 1
r3 6
sp (r1)
1
6
loc: cal0
2
Stack

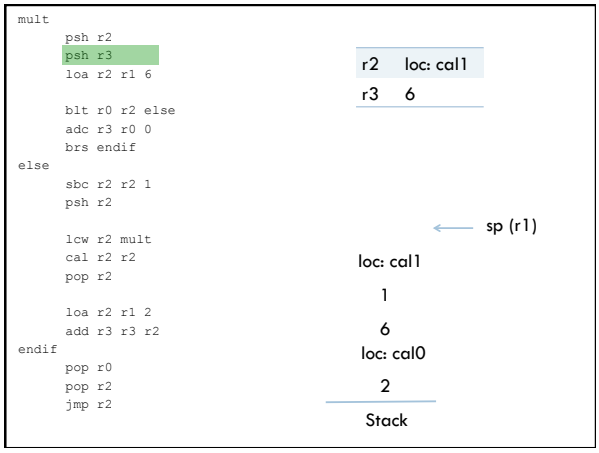

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: mult
r3 6
sp (r1)
1
6
loc: cal0
2
Stack

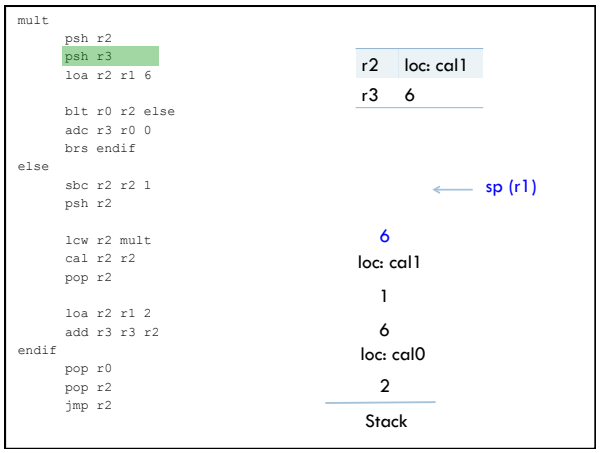

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: mult
r3 6
sp (r1)
1
6
loc: cal0
2
Stack

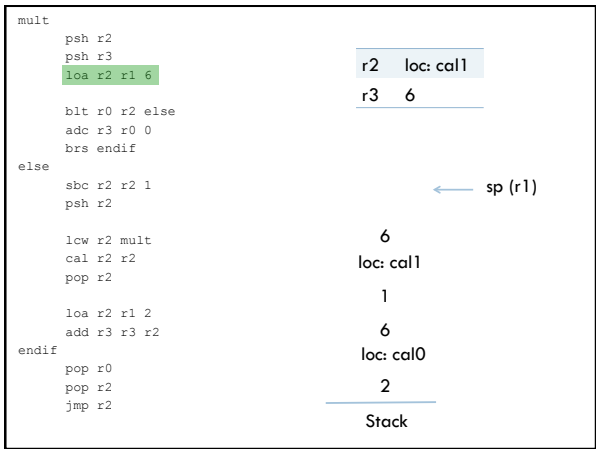

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 6
sp (r1)
1
6
loc: cal0
2
Stack

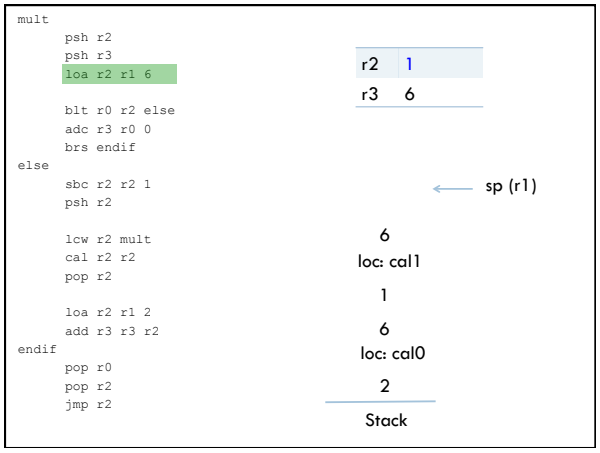

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 6
sp (r1)
1
6
loc: cal0
2
Stack

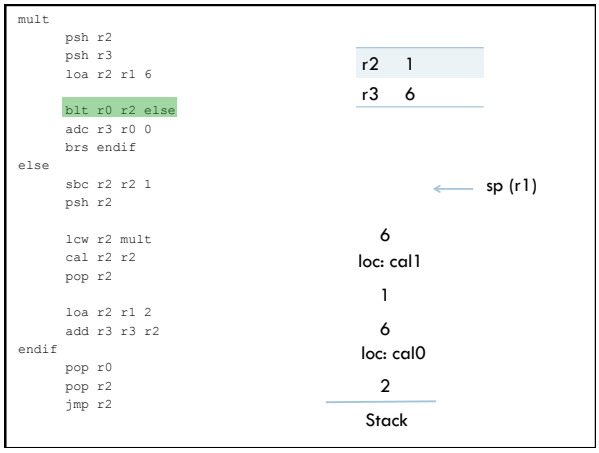

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 6
sp (r1)
loc: cal1
1
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 6
sp (r1)
loc: cal1
1
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 6
sp (r1)
6
loc: cal1
1
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 6
sp (r1)
6
loc: cal1
1
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 1
r3 6
sp (r1)
6
loc: cal1
1
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 1
r3 6
sp (r1)
6
loc: cal1
1
6
loc: cal0
2
Stack

```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1     <- highlighted
      psh r2

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

r2	1
r3	6

← sp (r1)

6
loc: cal1
1
6
loc: cal0
2

Stack

```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1     <- highlighted
      psh r2

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

r2	0
r3	6

← sp (r1)

6
loc: cal1
1
6
loc: cal0
2

Stack

```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1
      psh r2          <- highlighted

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

r2	0
r3	6

← sp (r1)

6
loc: cal1
1
6
loc: cal0
2

Stack

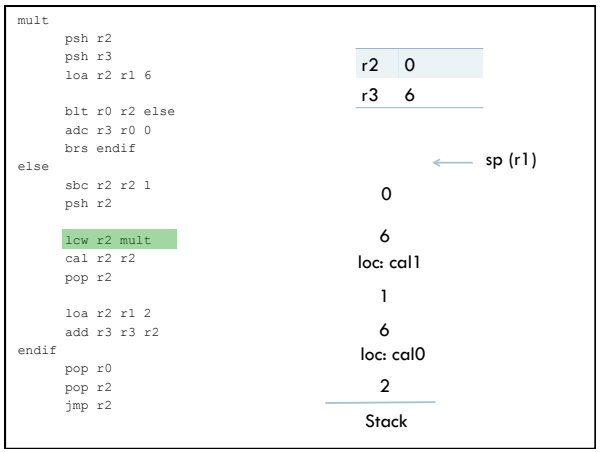
```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1
      psh r2          <- highlighted

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

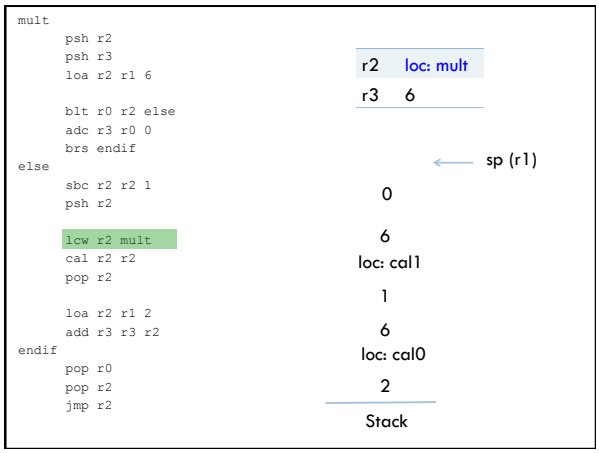
r2	0
r3	6

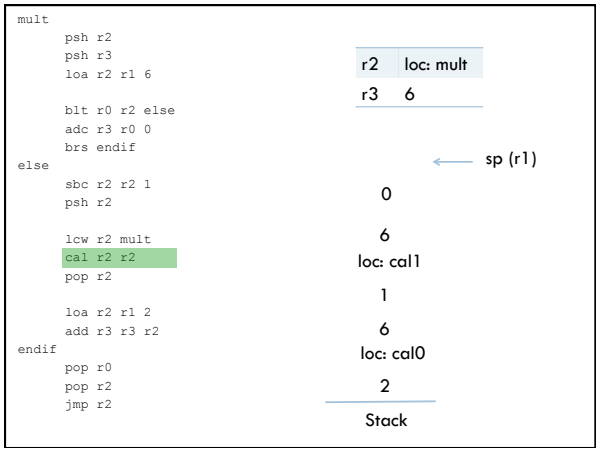
← sp (r1)

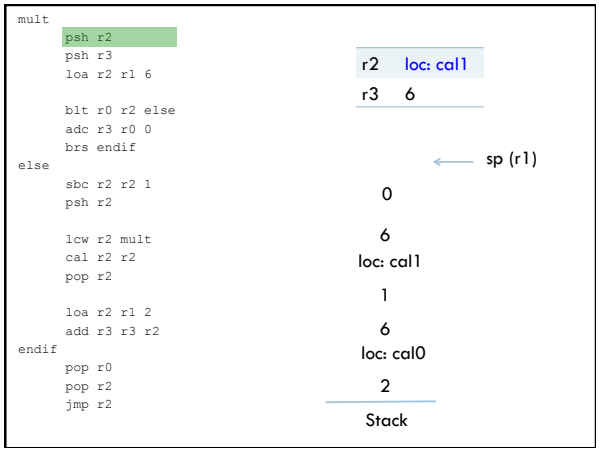
0
6
loc: cal1
1
6
loc: cal0
2

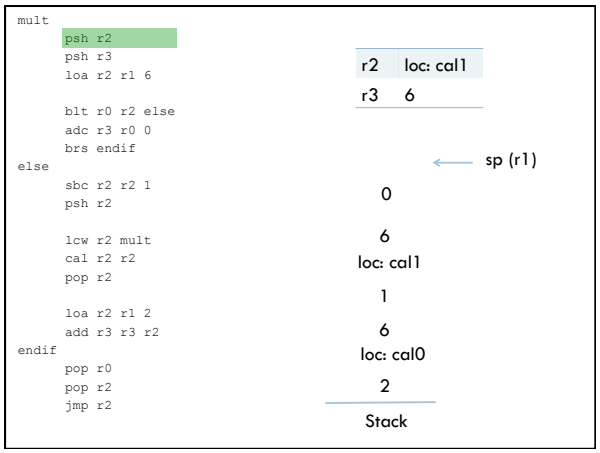
Stack

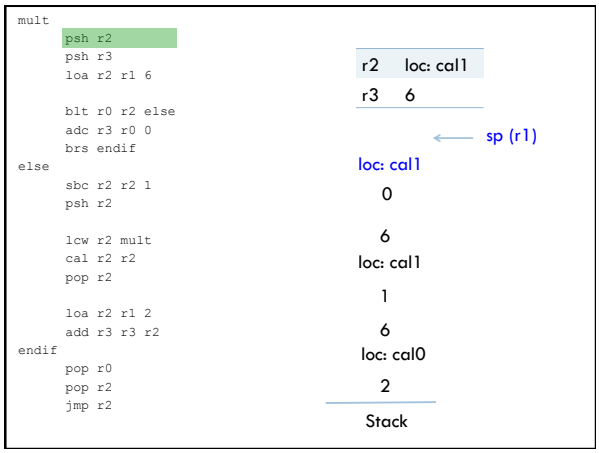

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 0
r3 6
sp (r1)
0
6
loc: cal1
1
6
loc: cal0
2
Stack

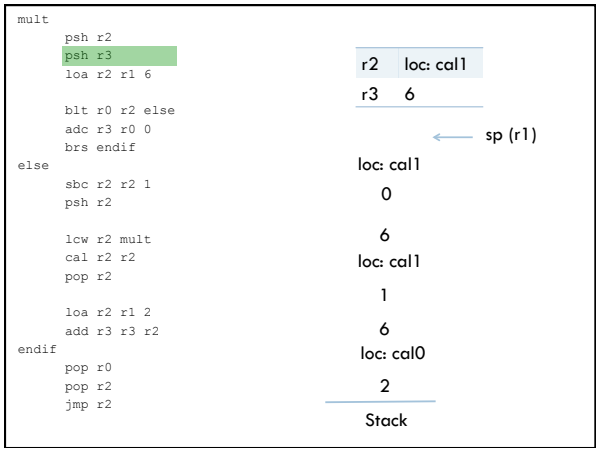

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: mult
r3 6
sp (r1)
0
6
loc: cal1
1
6
loc: cal0
2
Stack

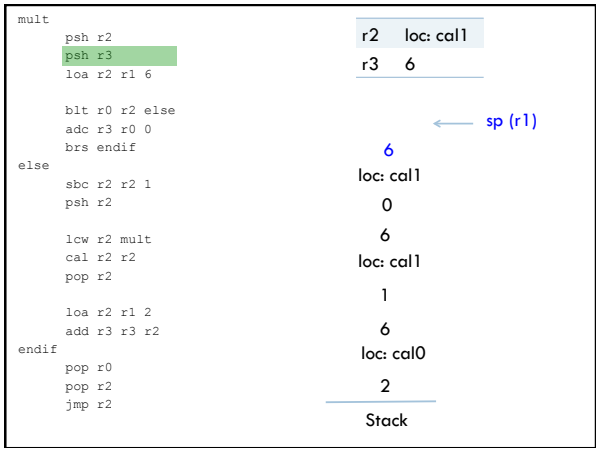

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: mult
r3 6
sp (r1)
0
6
loc: cal1
1
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 6
sp (r1)
0
6
loc: cal1
1
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 6
sp (r1)
0
6
loc: cal1
1
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 6
sp (r1)
loc: cal1
0
6
loc: cal1
1
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 6
sp (r1)
loc: cal1
0
6
loc: cal1
1
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 6
sp (r1)
6
loc: cal1
0
6
loc: cal1
1
6
loc: cal0
2
Stack

```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1
      psh r2

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

r2	loc: cal1
r3	6

← sp (r1)

6
loc: cal1
0
6
loc: cal1
1
6
loc: cal0
2

Stack

```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1
      psh r2

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

r2	0
r3	6

← sp (r1)

6
loc: cal1
0
6
loc: cal1
1
6
loc: cal0
2

Stack

```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1
      psh r2

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

r2	0
r3	6

← sp (r1)

6
loc: cal1
0
6
loc: cal1
1
6
loc: cal0
2

Stack

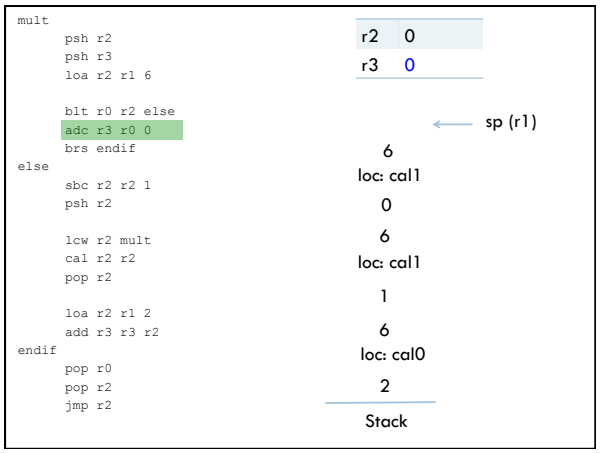
```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1
      psh r2

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

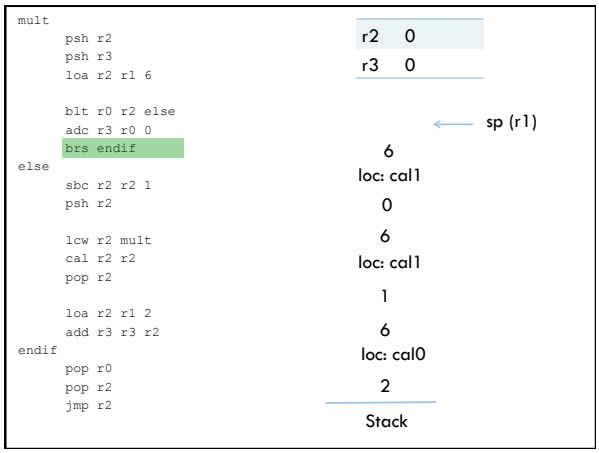
r2	0
r3	6

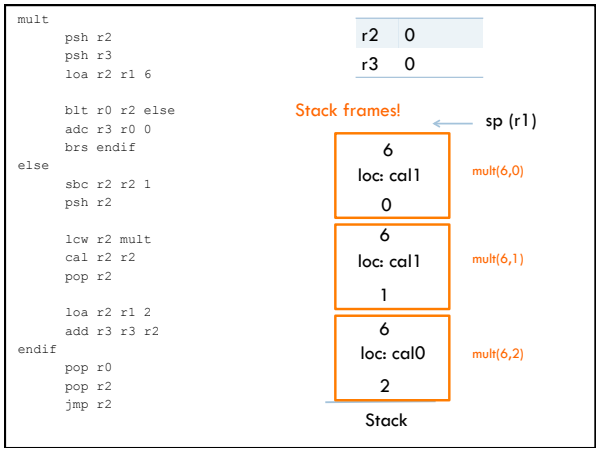
← sp (r1)

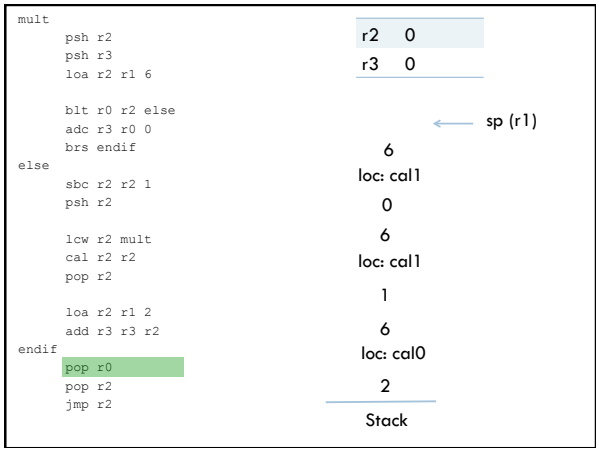
6
loc: cal1
0
6
loc: cal1
1
6
loc: cal0
2

Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 0
r3 0
sp (r1)
6
loc: cal1
0
6
loc: cal1
1
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 0
r3 0
sp (r1)
6
loc: cal1
0
6
loc: cal1
1
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 0
r3 0
Stack frames!
sp (r1)
6
loc: cal1
0
mult(6,0)
6
loc: cal1
1
mult(6,1)
6
loc: cal0
2
mult(6,2)
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 0
r3 0
sp (r1)
6
loc: cal1
0
6
loc: cal1
1
6
loc: cal0
2
Stack

```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1
      psh r2

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

r2	0
r3	0

We don't actually care about this value, but need to get it off the stack to cleanup… just put it in r0, which throws it away

← sp (r1)

loc: cal1
0
6
loc: cal1
1
6
loc: cal0
2

Stack

```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1
      psh r2

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

r2	0
r3	0

← sp (r1)

loc: cal1
0
6
loc: cal1
1
6
loc: cal0
2

Stack

```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1
      psh r2

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

r2	loc: cal1
r3	0

← sp (r1)

0
6
loc: cal1
1
6
loc: cal0
2

Stack

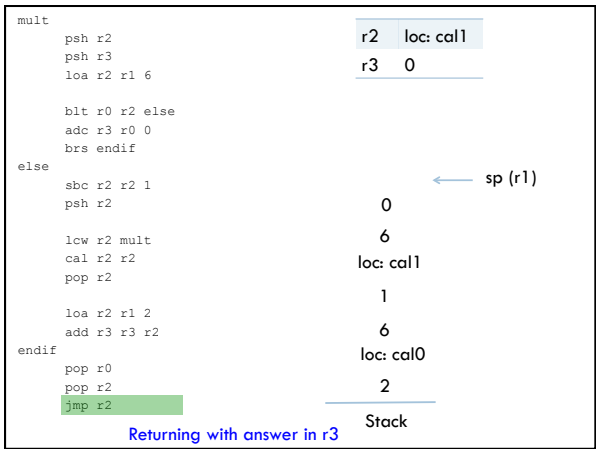
```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1
      psh r2

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

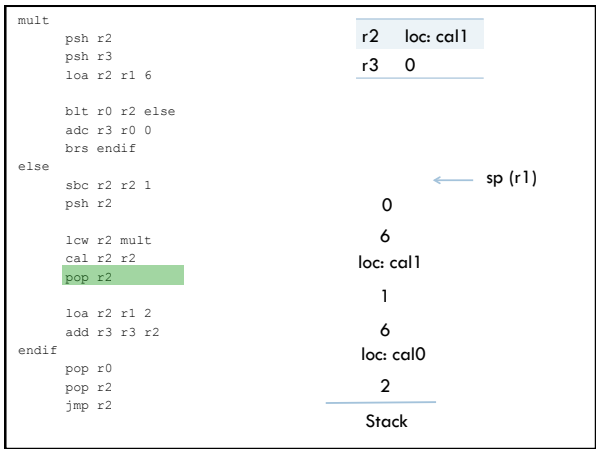
r2	loc: cal1
r3	0

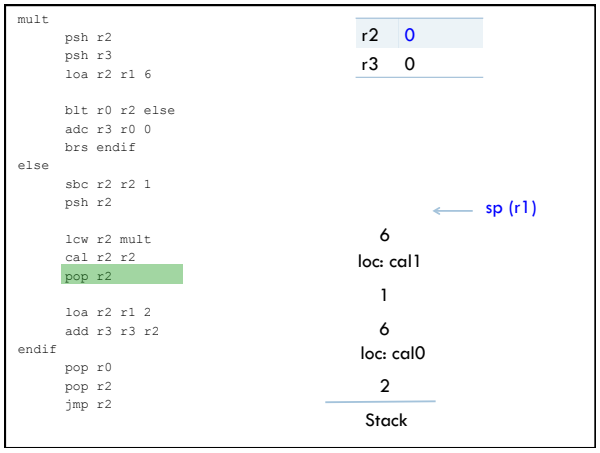
← sp (r1)

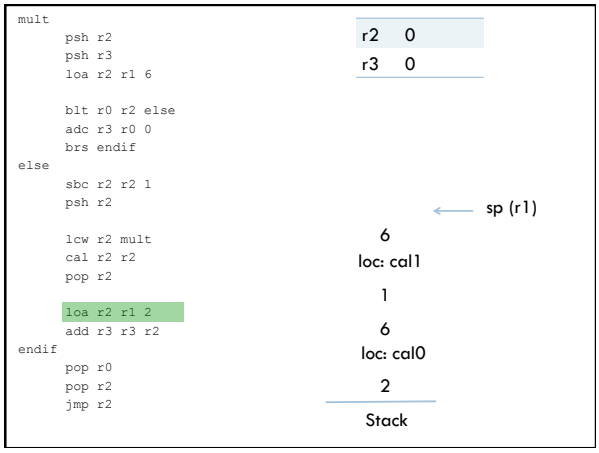
0
6
loc: cal1
1
6
loc: cal0
2

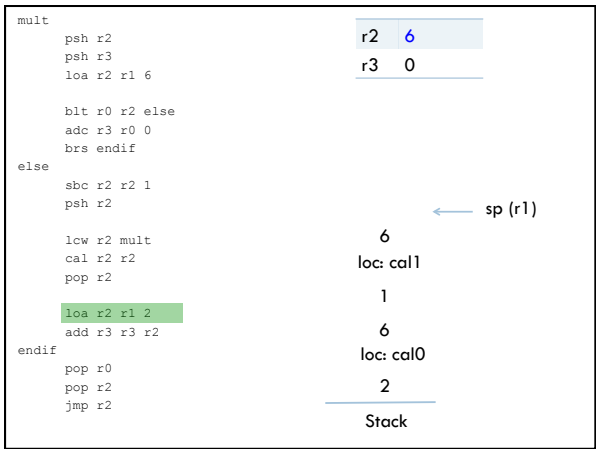
Stack

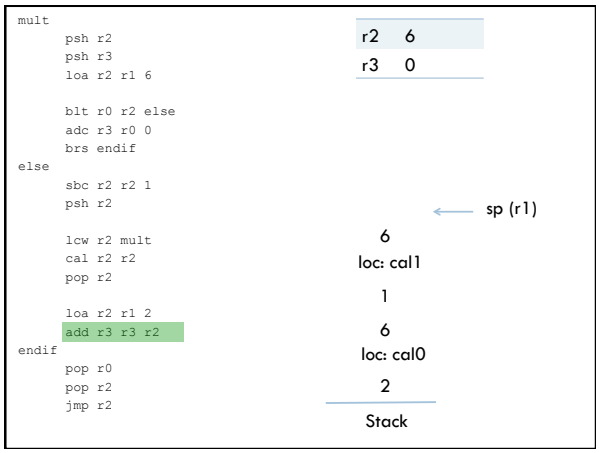

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 0
sp (r1)
0
6
loc: cal1
1
6
loc: cal0
2
Stack
Returning with answer in r3

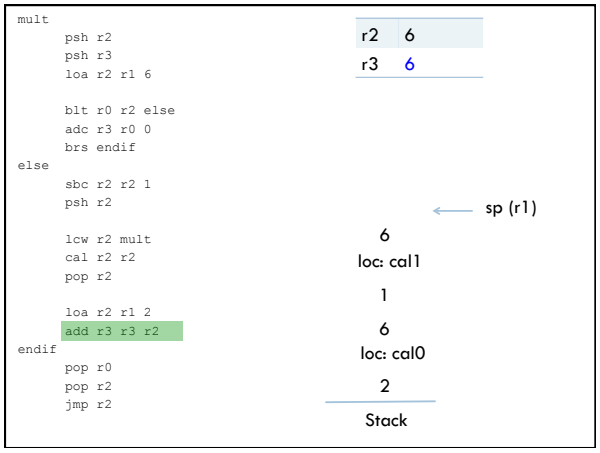

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 0
sp (r1)
0
6
loc: cal1
1
6
loc: cal0
2
Stack

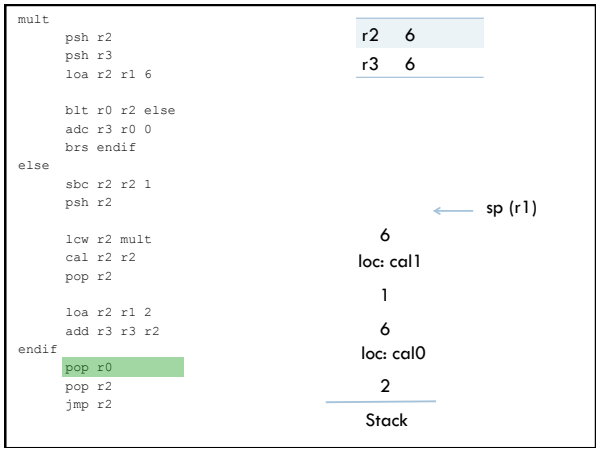

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 0
r3 0
sp (r1)
6
loc: cal1
1
6
loc: cal0
2
Stack

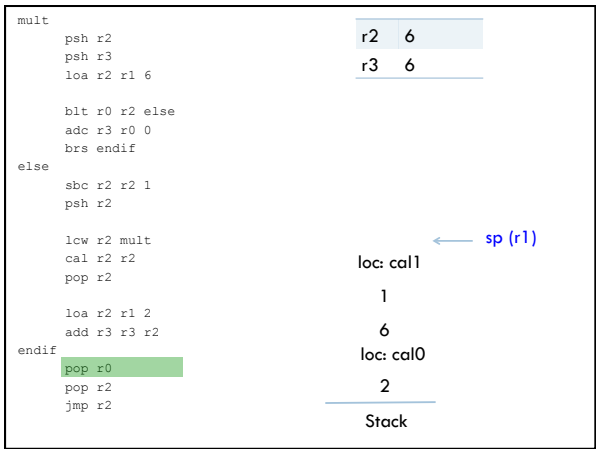

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 0
r3 0
sp (r1)
6
loc: cal1
1
6
loc: cal0
2
Stack

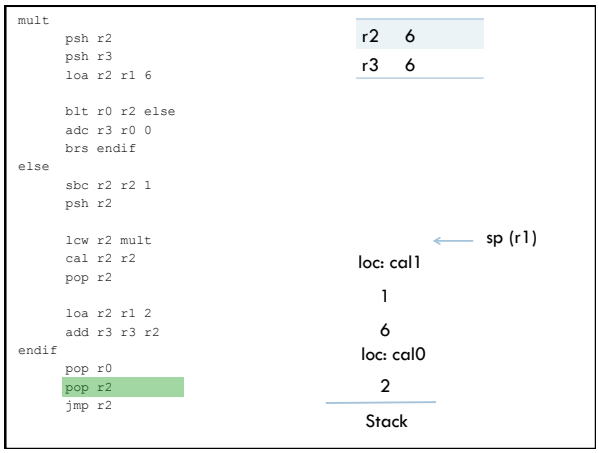

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 6
r3 0
sp (r1)
6
loc: cal1
1
6
loc: cal0
2
Stack

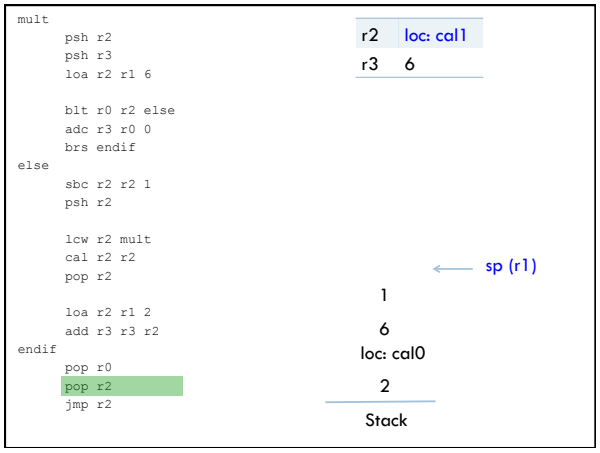

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 6
r3 0
sp (r1)
6
loc: cal1
1
6
loc: cal0
2
Stack

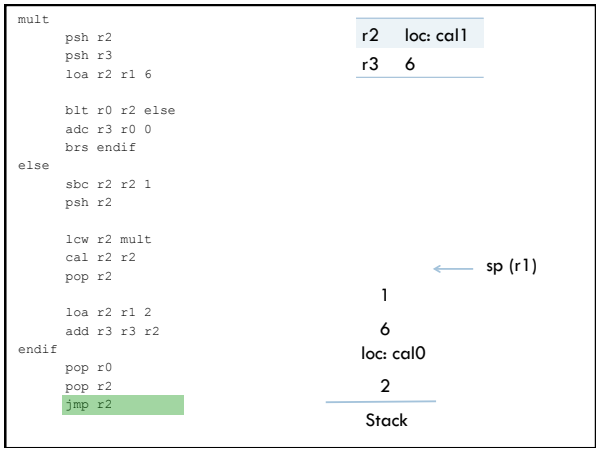

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 6
r3 6
sp (r1)
6
loc: cal1
1
6
loc: cal0
2
Stack

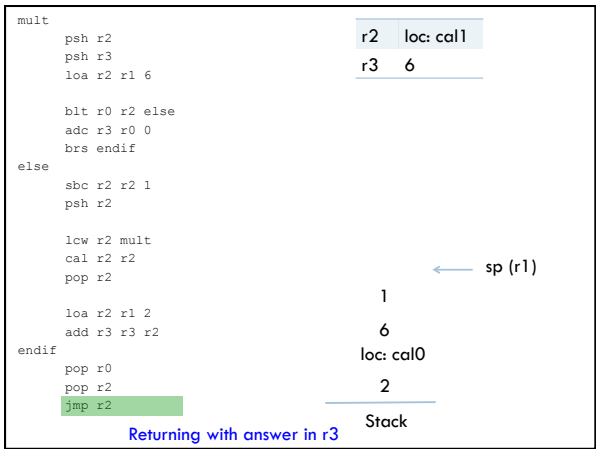

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 6
r3 6
sp (r1)
6
loc: cal1
1
6
loc: cal0
2
Stack

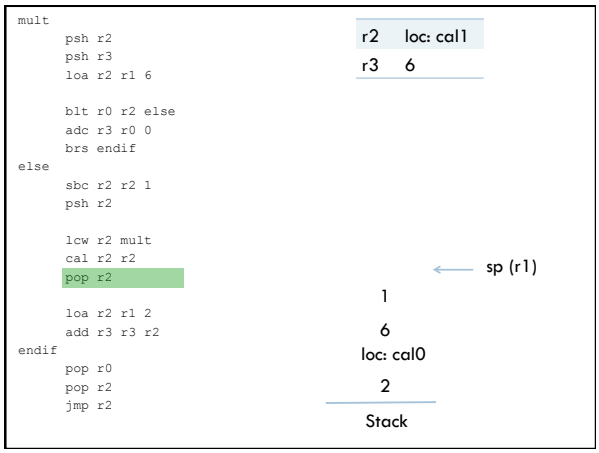

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 6
r3 6
sp (r1)
loc: cal1
1
6
loc: cal0
2
Stack

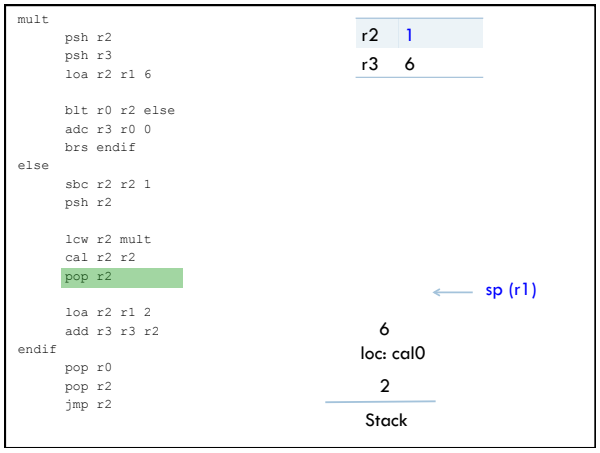

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 6
r3 6
sp (r1)
loc: cal1
1
6
loc: cal0
2
Stack

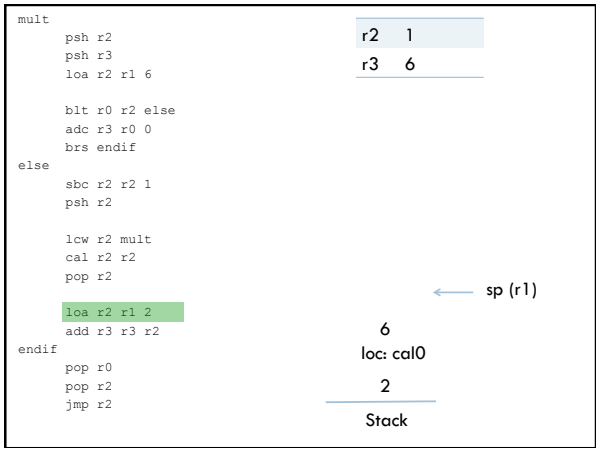

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 6
sp (r1)
1
6
loc: cal0
2
Stack

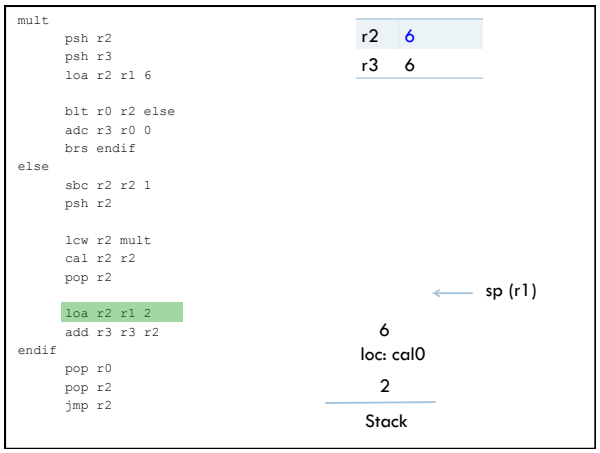

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 6
sp (r1)
1
6
loc: cal0
2
Stack

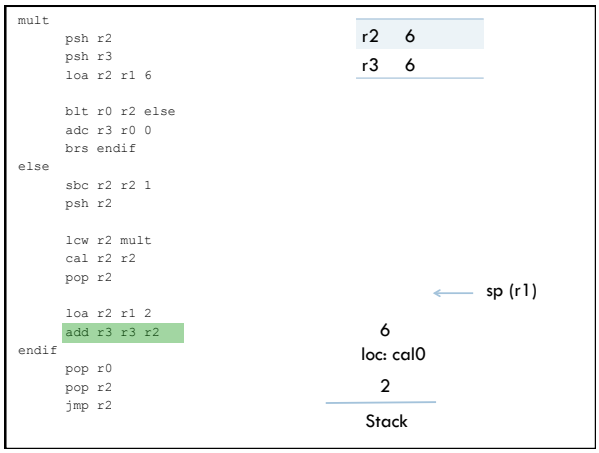

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 6
sp (r1)
1
6
loc: cal0
2
Stack
Returning with answer in r3

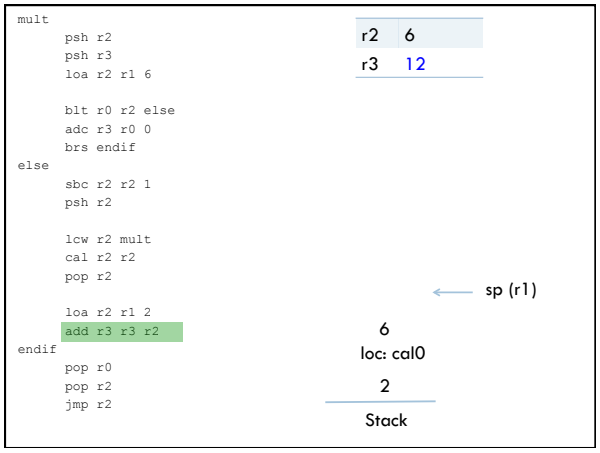

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 loc: cal1
r3 6
sp (r1)
1
6
loc: cal0
2
Stack

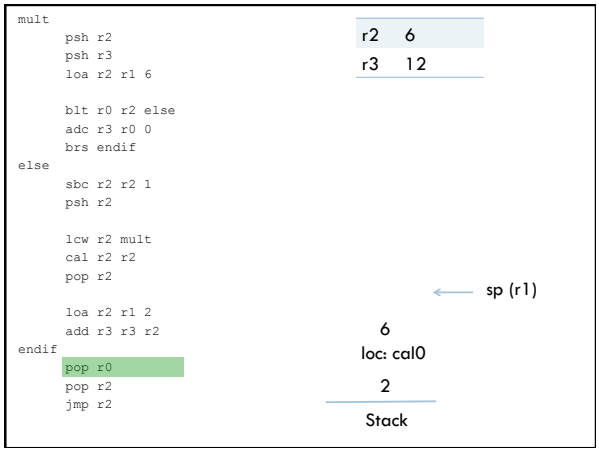

mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 1
r3 6
sp (r1)
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 1
r3 6
sp (r1)
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 6
r3 6
sp (r1)
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 6
r3 6
sp (r1)
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 6
r3 12
sp (r1)
6
loc: cal0
2
Stack


mult
psh r2
psh r3
loa r2 r1 6
blt r0 r2 else
adc r3 r0 0
brs endif
else
sbc r2 r2 1
psh r2
lcw r2 mult
cal r2 r2
pop r2
loa r2 r1 2
add r3 r3 r2
endif
pop r0
pop r2
jmp r2
r2 6
r3 12
sp (r1)
6
loc: cal0
2
Stack

```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1
      psh r2

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

r2	6
r3	12

sp (r1)

loc: cal0

2

Stack

```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1
      psh r2

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

r2	6
r3	12

sp (r1)

loc: cal0

2

Stack

```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1
      psh r2

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

r2	loc: cal0
r3	12

sp (r1)

2

Stack

```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1
      psh r2

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

r2	loc: cal0
r3	12

sp (r1)

2

Stack

```
mult
      psh r2
      psh r3
      loa r2 r1 6

      blt r0 r2 else
      adc r3 r0 0
      brs endif
else
      sbc r2 r2 1
      psh r2

      lcw r2 mult
      cal r2 r2
      pop r2

      loa r2 r1 2
      add r3 r3 r2
endif
      pop r0
      pop r2
      jmp r2
```

r2	loc: cal0
r3	12

← sp (r1)

2

Stack

Returning with answer in r3

Calling mult

```
      loa r3 r0
      loa r2 r0

      psh r2
      lcw r2 mult
      cal r2 r2

      pop r2

      sto r0 r3
      hlt
```

r2	loc: cal0
r3	12

← sp (r1)

2

Stack

Calling mult

```
      loa r3 r0
      loa r2 r0

      psh r2
      lcw r2 mult
      cal r2 r2

      pop r2

      sto r0 r3
      hlt
```

r2	2
r3	12

← sp (r1)

Stack

Calling mult

```
      loa r3 r0
      loa r2 r0

      psh r2
      lcw r2 mult
      cal r2 r2

      pop r2

      sto r0 r3
      hlt
```

r2	2
r3	12

← sp (r1)

Stack

Calling mult

```
loa r3 r0
loa r2 r0

psh r2
lcw r2 mult
cal r2 r2

pop r2

sto r0 r3
hlt
```

r2	2
r3	12

Print the answer: 12!

Calling mult

```
loa r3 r0
loa r2 r0

psh r2
lcw r2 mult
cal r2 r2

pop r2

sto r0 r3
hlt
```

r2	2
r3	12

Print the answer: 12!

Run mult.a41 in simulator

CS41B programming advice

1. Match your push and pops
2. Follow the register conventions
3. Develop code incrementally
4. Debugging: write out stack, registers, etc. on paper and compare against system execution

Examples from this lecture

http://www.cs.pomona.edu/~dkauchak/classes/cs52/examples/cs41b/