THE C0VM

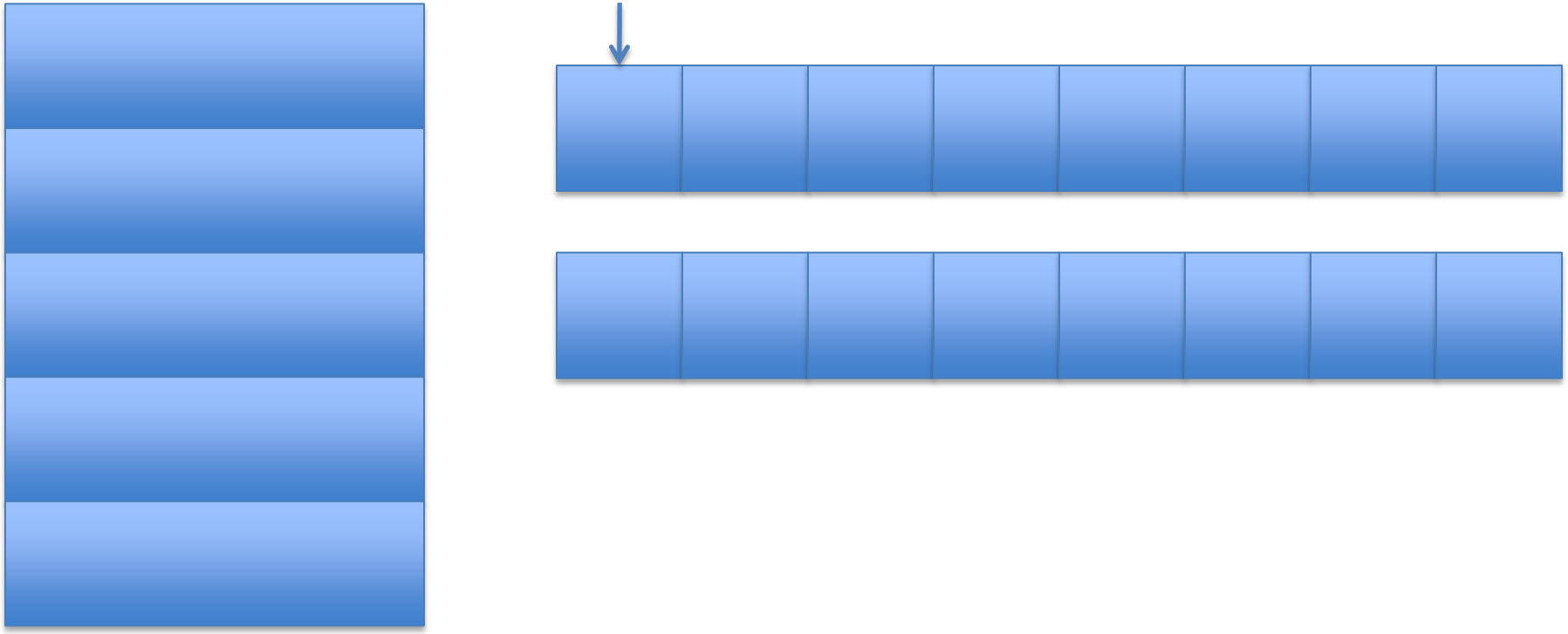
Peter Wei

PC (program counter) = 0

stack_new()

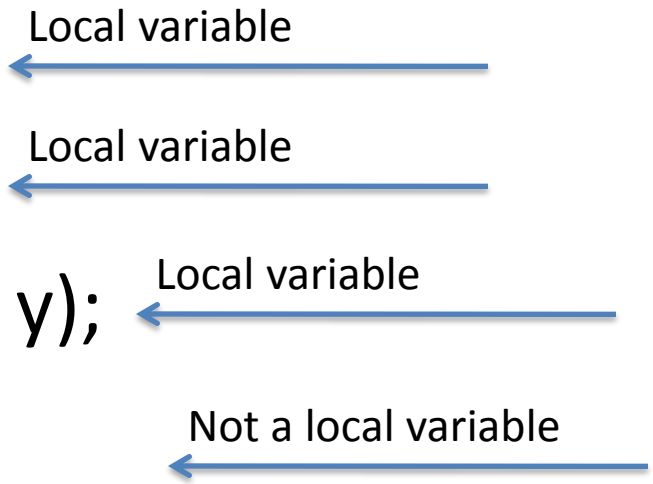
S- stack

ubyte *P- program pointer



Example Code

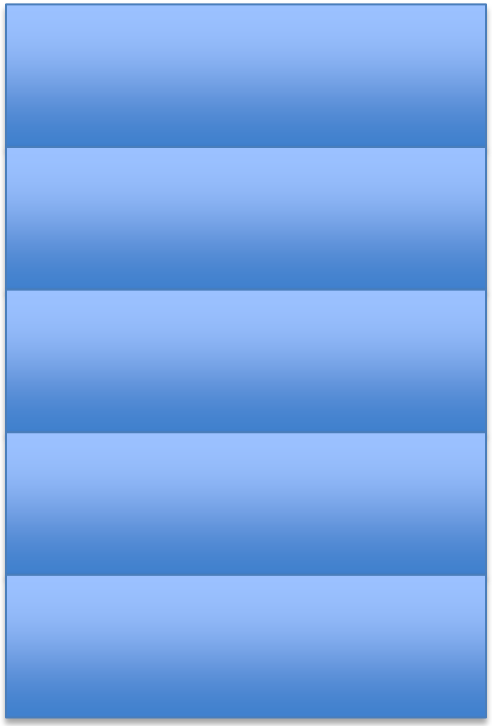
```
int main() {
  int x = 5;
  int y = 2;
  int z = exp(x, y);
  return z;
}
```



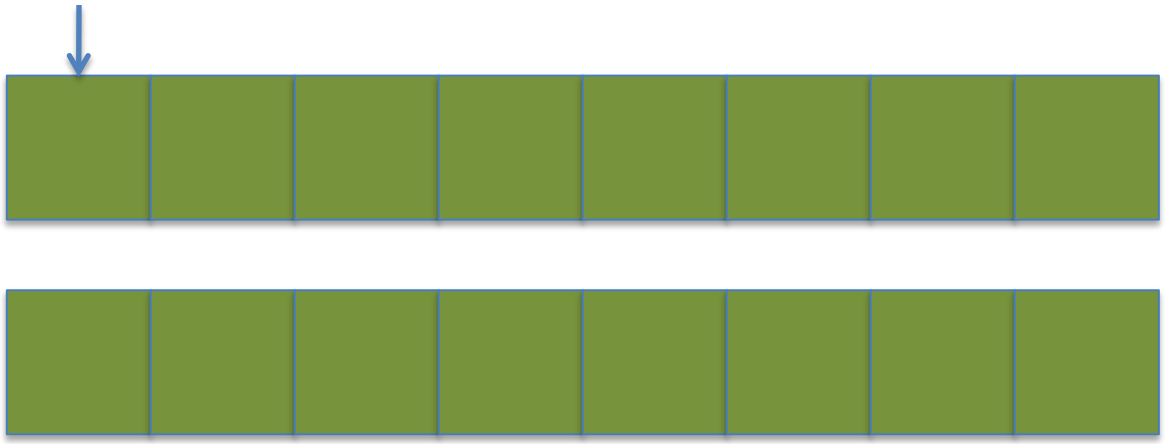
PC (program counter) = 0

stack_new()

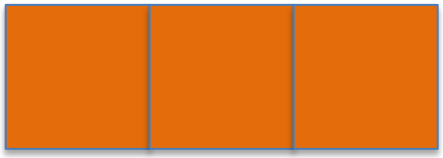
S- stack



ubyte *P- program pointer



V- variables



xmalloc(sizeof(c0_value)*num_vars)

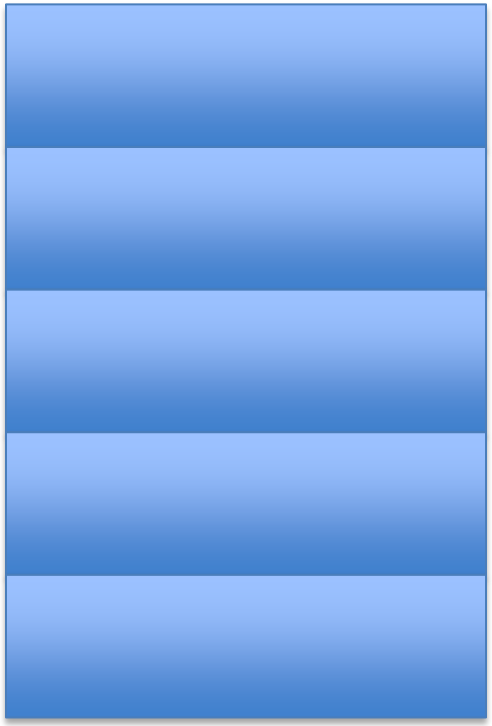
Call stack

```
#<main>
00 00              # number of arguments = 0
00 03              # number of local variables = 3
00 14              # code length = 20 bytes
10 05    # bipush 5         # 5
36 00    # vstore 0         # x = 5;
10 02    # bipush 2         # 2
36 01    # vstore 1         # y = 2;
15 00    # vload 0          # x
15 01    # vload 1          # y
B8 00 01 # invokestatic 1   # exp(x, y)
36 02    # vstore 2         # z = exp(x, y);
15 02    # vload 2          # z
B0       # return           #
```

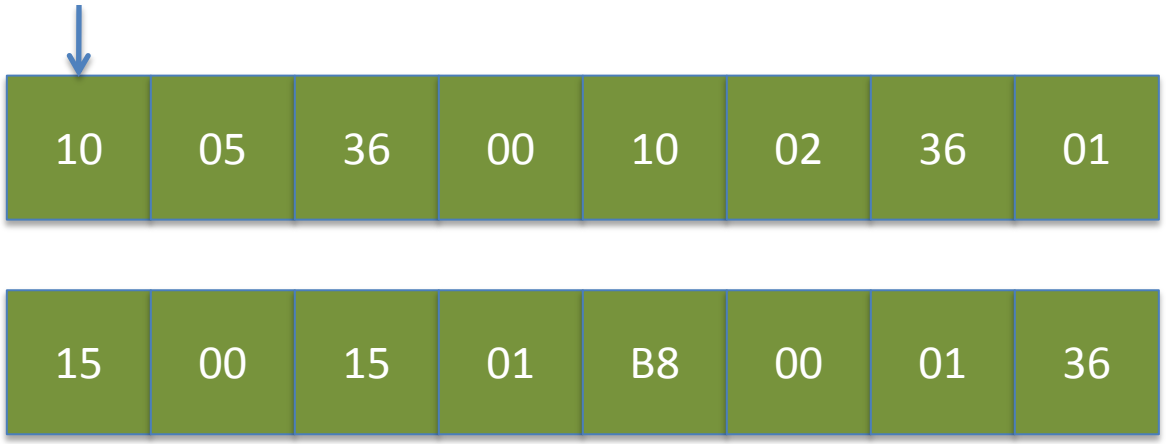
PC (program counter) = 0

stack_new()

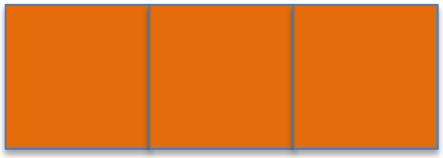
S- stack



P[pc]



V- variables



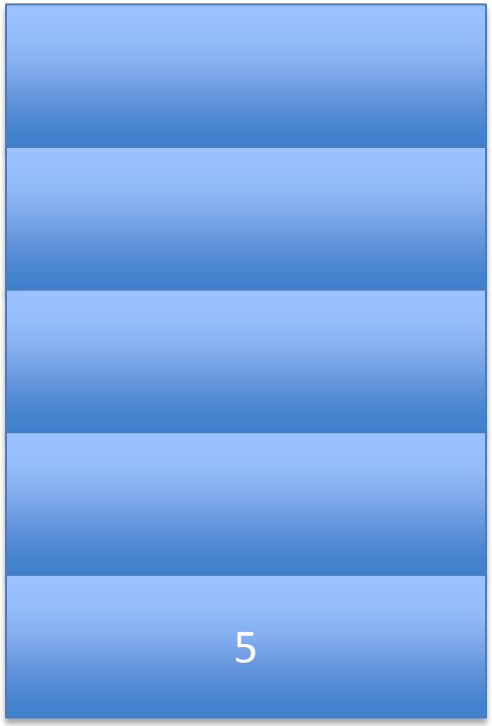
xmalloc(sizeof(c0_value)*num_vars)

Call stack

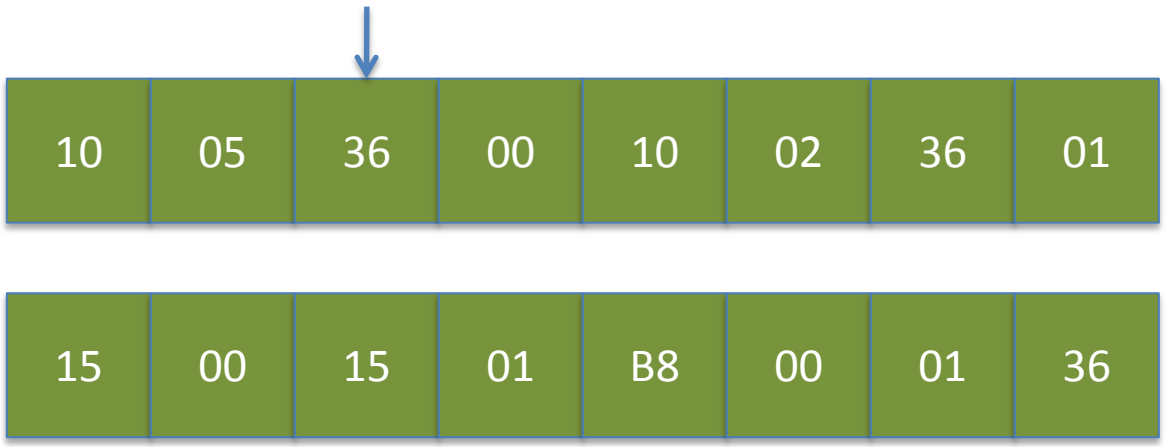
PC (program counter) = 2

stack_new()

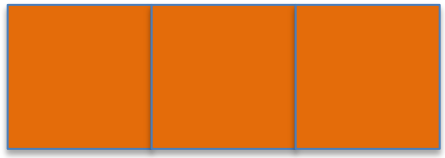
S- stack



P[pc]



V- variables



xmalloc(sizeof(c0_value)*num_vars)

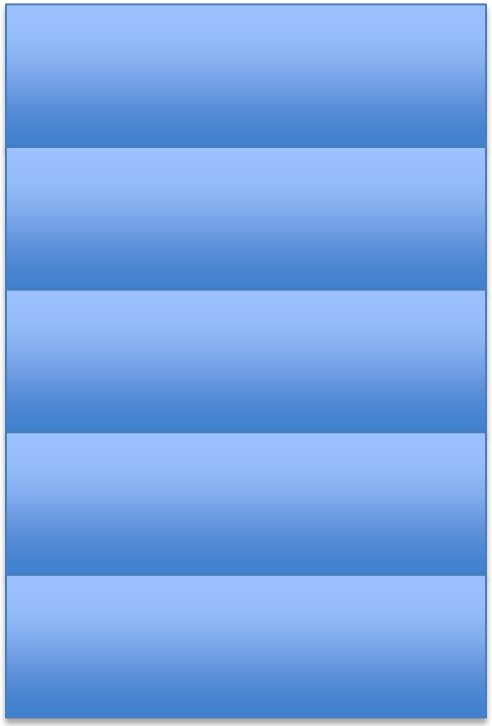
Call stack

After bipush 5

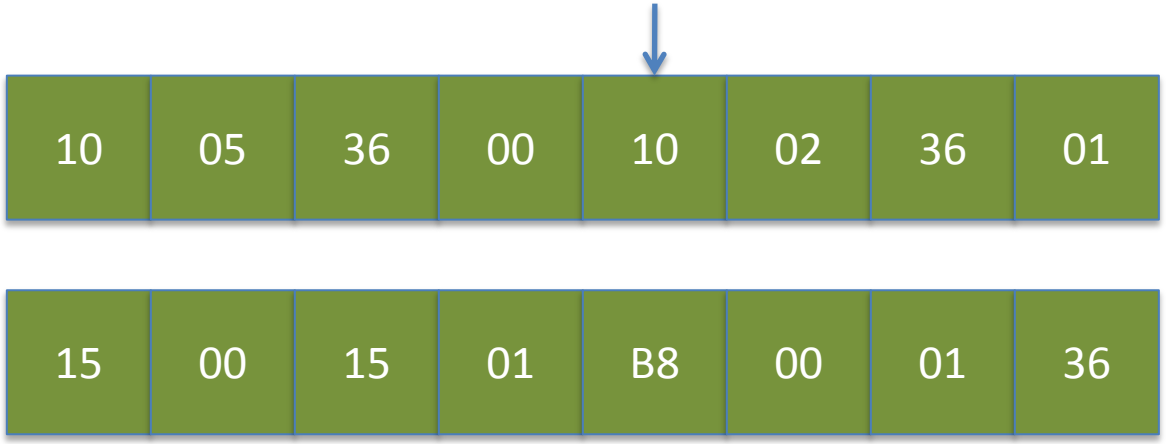
PC (program counter) = 4

stack_new()

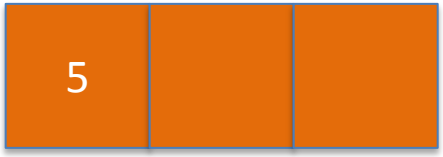
S- stack



P[pc]



V- variables



xmalloc(sizeof(c0_value)*num_vars)

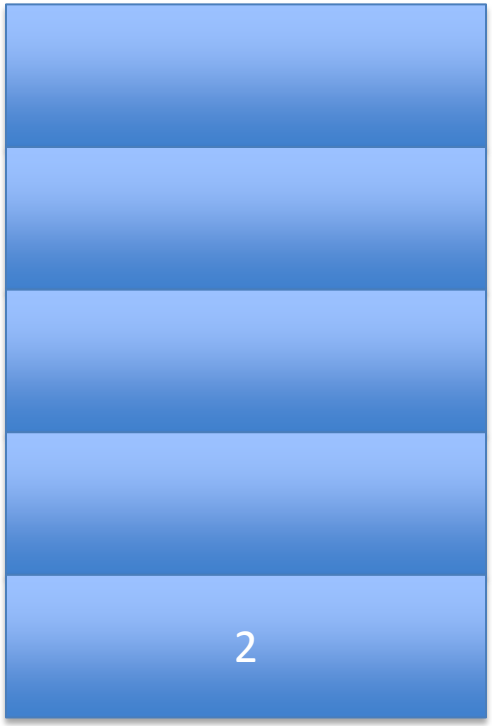
Call stack

After vstore 0 (pop from stack, put in V[0])

PC (program counter) = 6

stack_new()

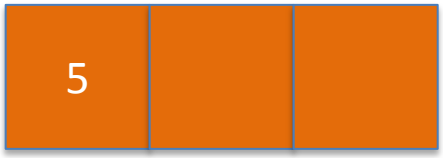
S- stack



P[pc]

10	05	36	00	10	02	36	01
15	00	15	01	B8	00	01	36

V- variables



xmalloc(sizeof(c0_value)*num_vars)

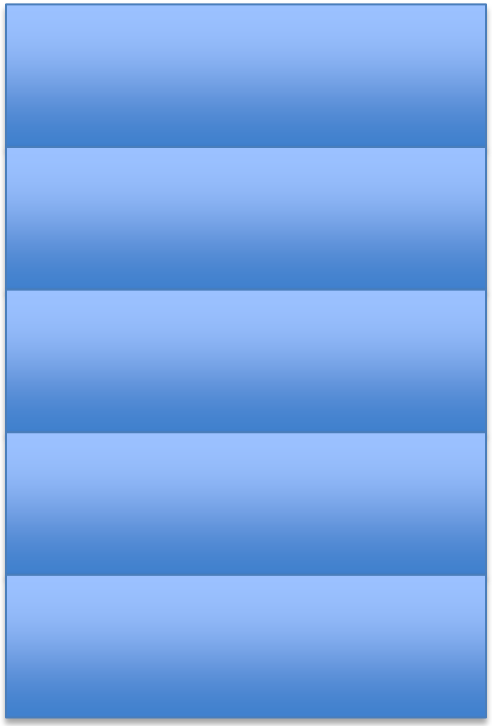
After Bipush 2

Call stack

PC (program counter) = 8

stack_new()

S- stack



10	05	36	00	10	02	36	01

P[pc]

15	00	15	01	B8	00	01	36

V- variables

xmalloc(sizeof(c0_value)*num_vars)

5	2	

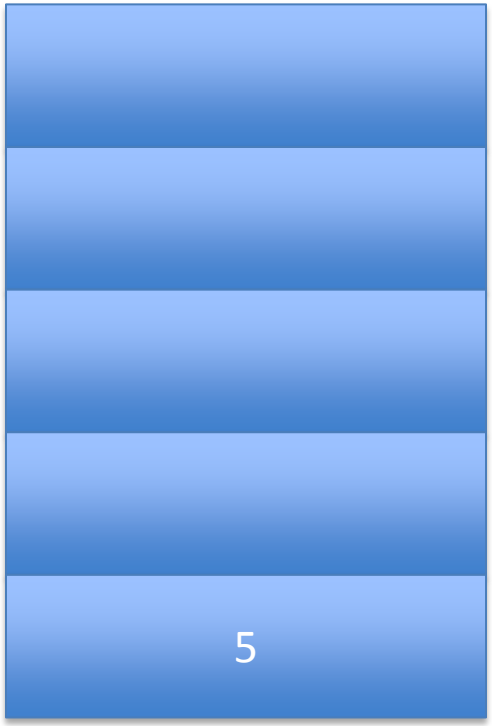
After vstore 1

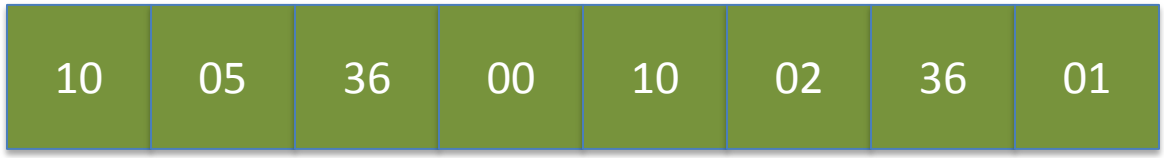
Call stack

PC (program counter) = 10

stack_new()

S- stack





P[pc]

V- variables

xmalloc(sizeof(c0_value)*num_vars)

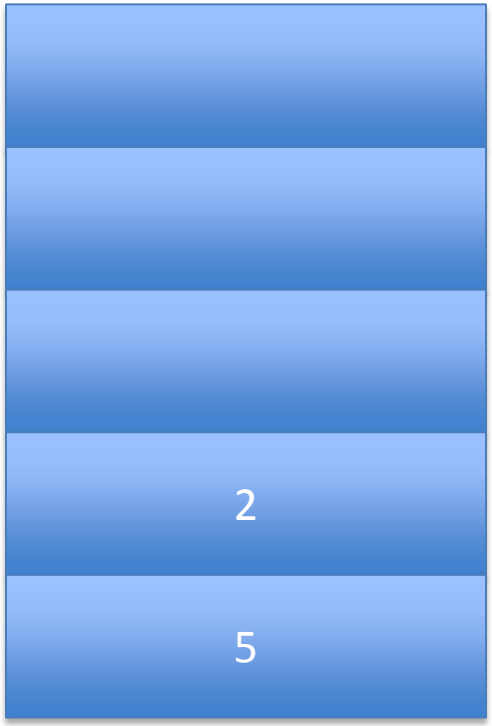
Call stack

After vload 0 (take V[0] and push onto S)

PC (program counter) = 12

stack_new()

S- stack



10	05	36	00	10	02	36	01

P[pc]

15	00	15	01	B8	00	01	36

V- variables

xmalloc(sizeof(c0_value)*num_vars)

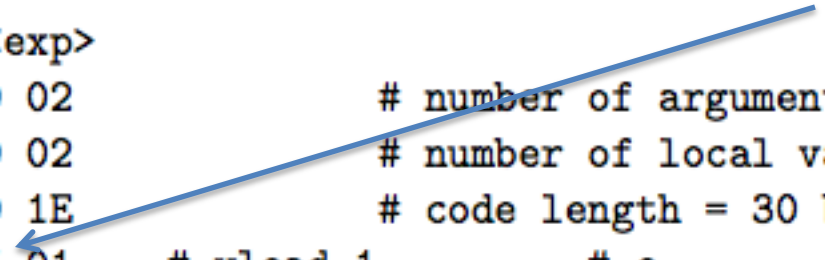
Call stack

After vload 1 (take V[1] and push onto S)

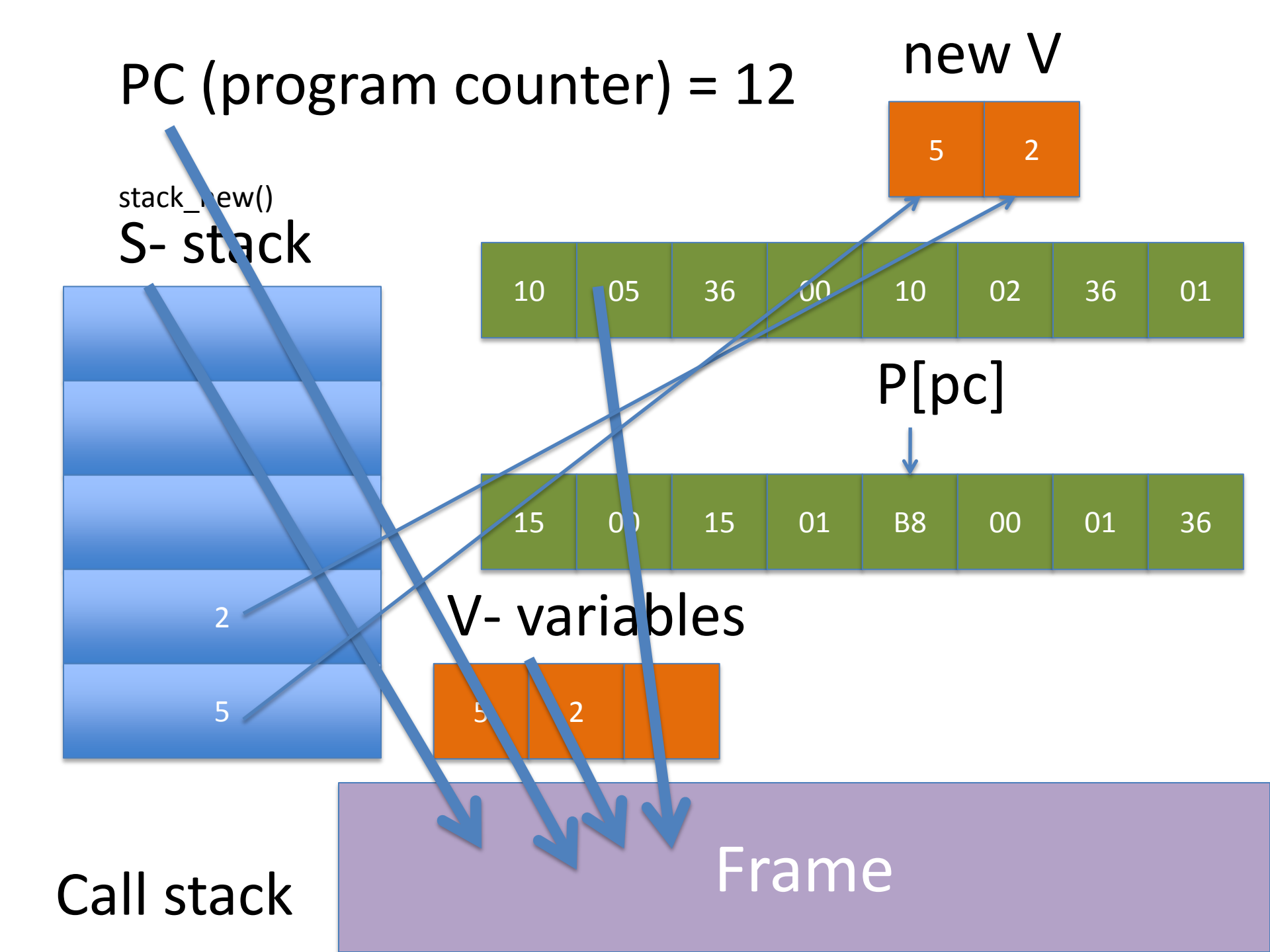
Main Code

```
#<main>
00 00              # number of arguments = 0
00 03              # number of local variables = 3
00 14              # code length = 20 bytes
10 05     # bipush 5          # 5
36 00     # vstore 0          # x = 5;
10 02     # bipush 2          # 2
36 01     # vstore 1          # y = 2;
15 00     # vload 0           # x
15 01     # vload 1           # y
B8 00 01  # invokestatic 1    # exp(x, y)
36 02     # vstore 2          # z = exp(x, y);
15 02     # vload 2           # z
B0        # return            #
```

Invokestatic- call another function, in this case, function 1 which is exp



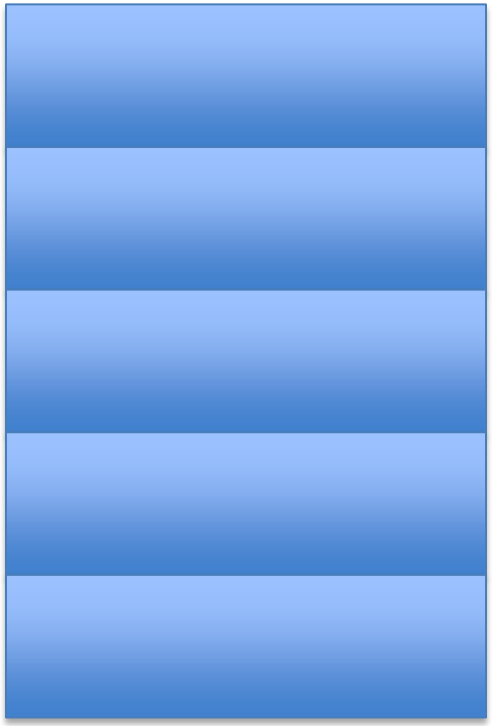
```
#<exp>
00 02              # number of arguments = 2
00 02              # number of local variables = 2
00 1E              # code length = 30 bytes
15 01    # vload 1          # e
10 00    # bipush 0         # 0
9F 00 06 # if_cmpeq +6      # if (e == 0) goto <00:then>
A7 00 09 # goto +9           # goto <01:else>
# <00:then>
10 01    # bipush 1         # 1
B0       # return           #
A7 00 11 # goto +17          # goto <02:endif>
# <01:else>
15 00    # vload 0          # b
15 00    # vload 0          # b
15 01    # vload 1          # e
10 01    # bipush 1         # 1
64       # isub             # (e - 1)
B8 00 01 # invokestatic 1   # exp(b, (e - 1))
68       # imul             # (b * exp(b, (e - 1)))
B0       # return           #
# <02:endif>
```


PC (program counter) = 12
new V
5
2
stack_new()
S- stack
10
05
36
00
10
02
36
01
P[pc]
15
01
15
01
B8
00
01
36
2
5
V- variables
5
2
Call stack
Frame

PC reset to 0

PC (program counter) = 0

S1



P1[pc]

15	01	10	00	9F	00	06	A7

00	09	10	01	B0	A7	00	11

V1

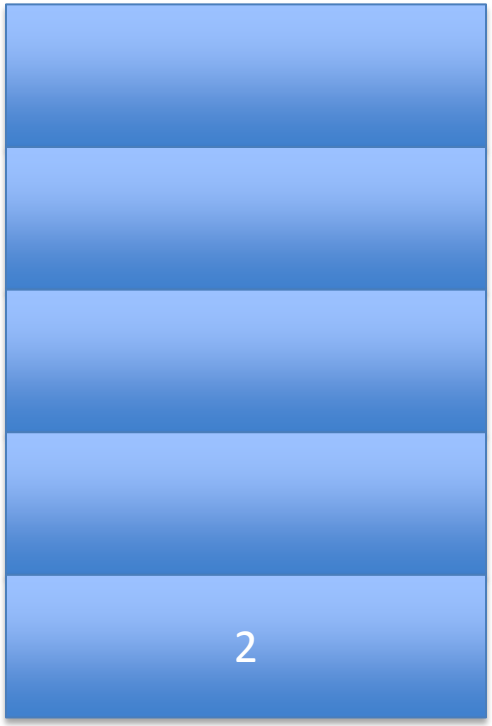
5	2

Call stack

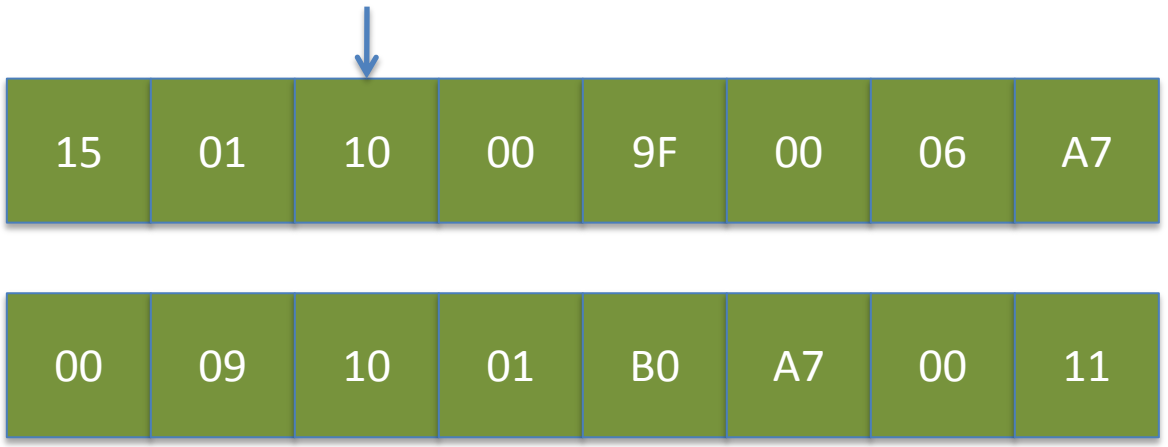
S, P, V, pc

PC (program counter) = 2

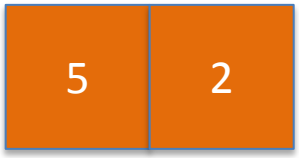
S1



P1[pc]



V1



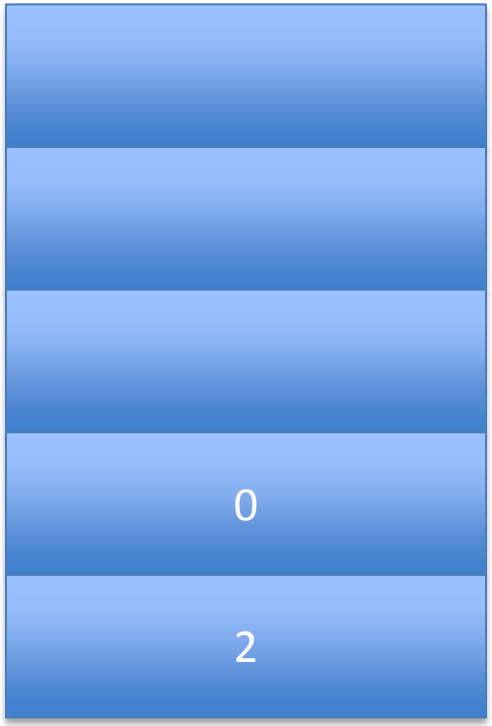
after vload 1

Call stack

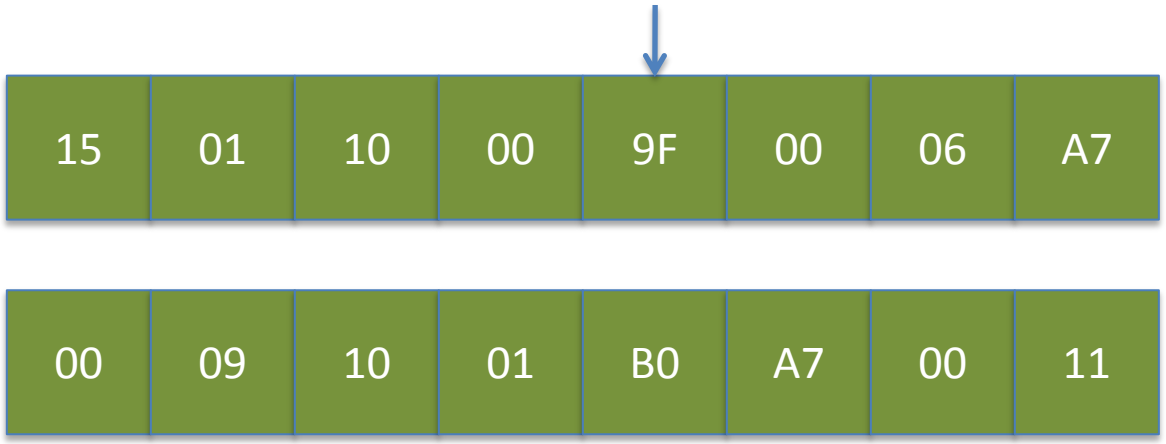
S, P, V, pc

PC (program counter) = 4

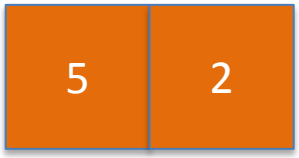
S1



P1[pc]



V1



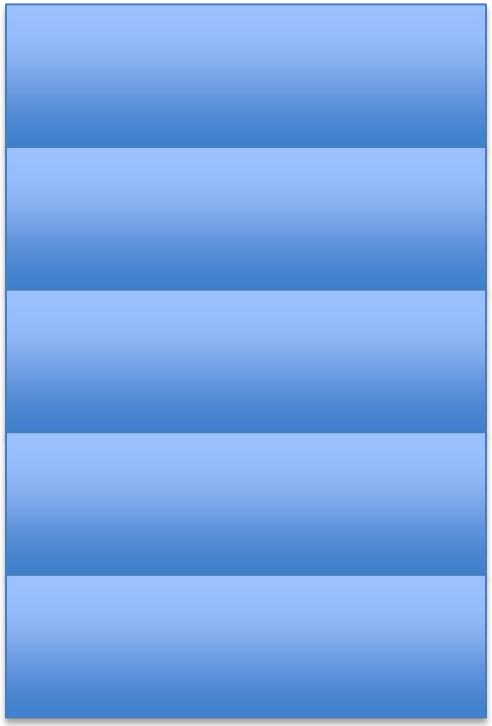
bipush 0

Call stack

S, P, V, pc

PC (program counter) = 7

S1



P1[pc]

15	01	10	00	9F	00	06	A7

00	09	10	01	B0	A7	00	11

V1

5	2

after if_cmpeq +6-
pop 2 off S, if =, +6

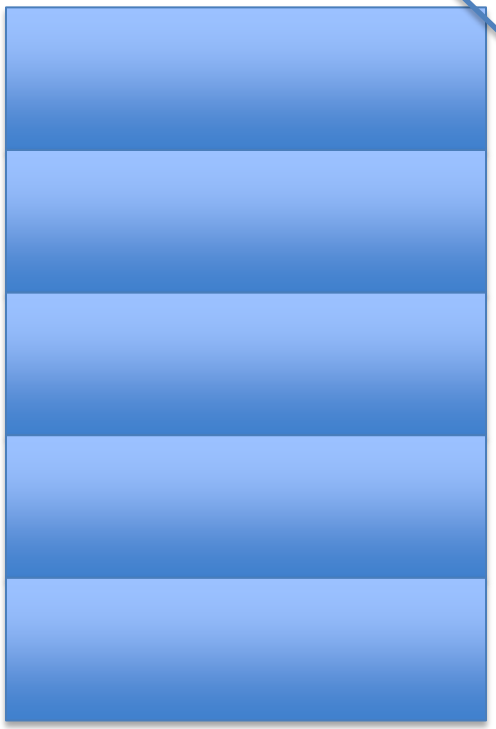
Call stack

S, P, V, pc

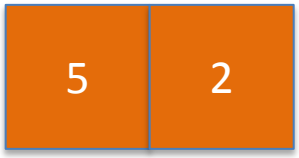
PC (program counter) = 16

15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

S1



V1



P1[pc]

after goto +9- jump 9 bytes

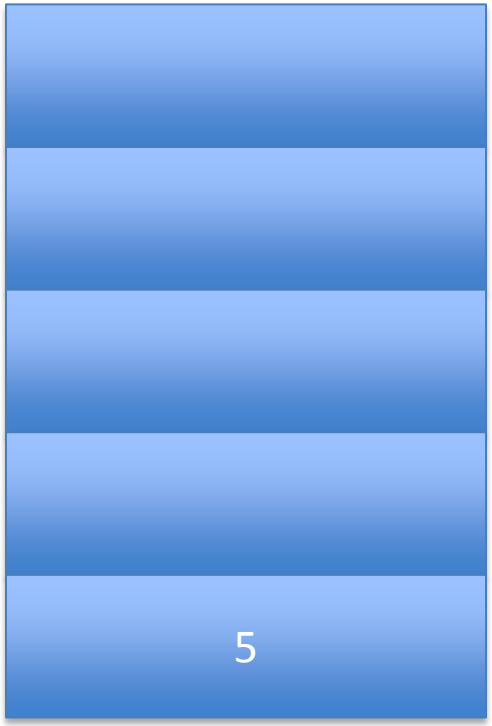
Call stack

S, P, V, pc

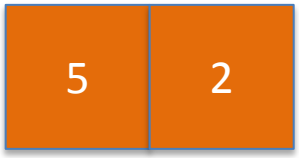
PC (program counter) = 18

15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

S1



V1



P1[pc]

after vload 0

Call stack

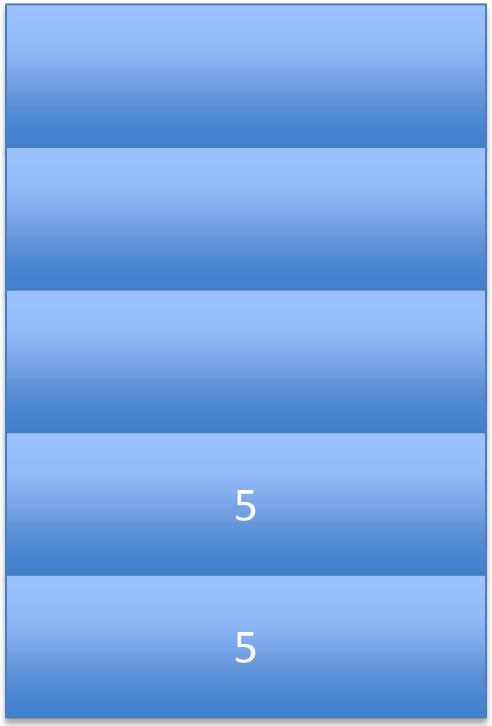
S, P, V, pc

PC (program counter) = 20

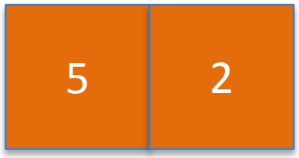
15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

P1[pc]

S1



V1



after vload 0

Call stack

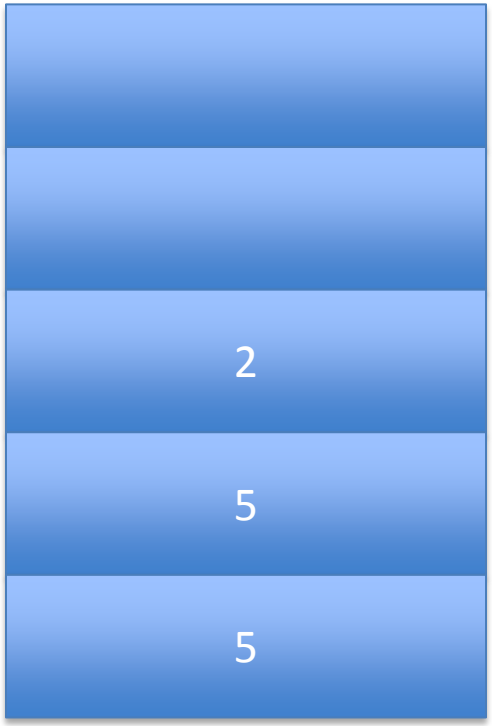
S, P, V, pc

PC (program counter) = 22

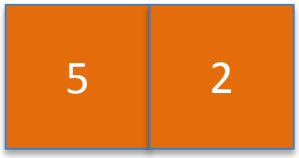
15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

P1[pc]

S1



V1



after vload 1

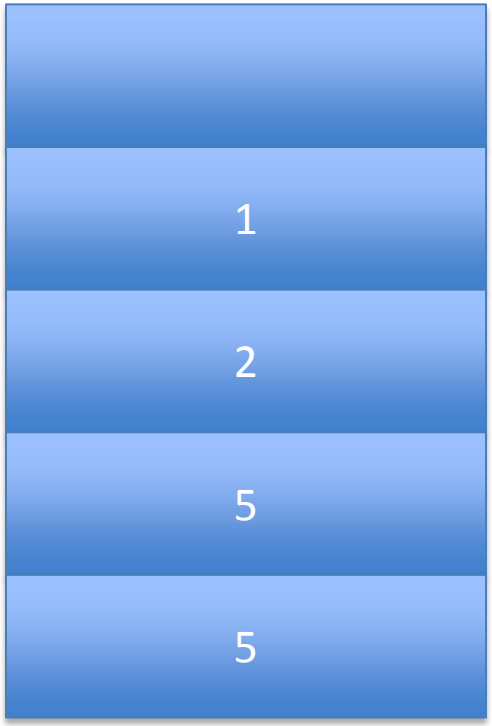
Call stack

S, P, V, pc

PC (program counter) = 24

15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

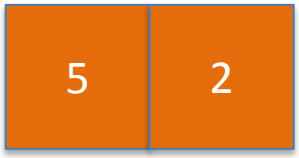
S1



P1[pc]

after bipush 1

V1



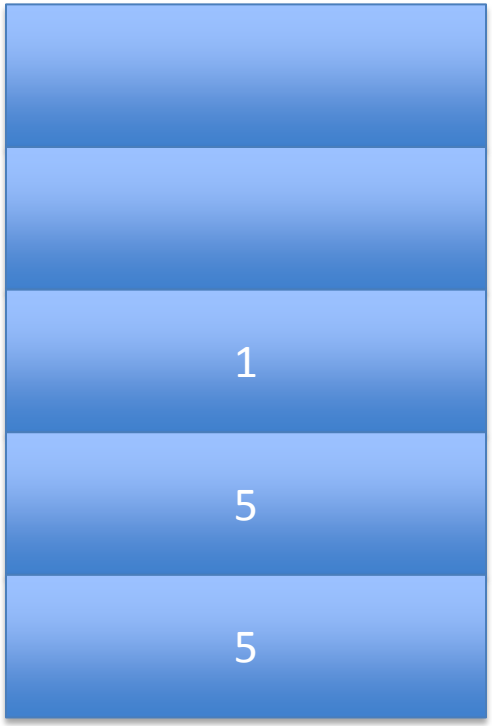
Call stack

S, P, V, pc

PC (program counter) = 25

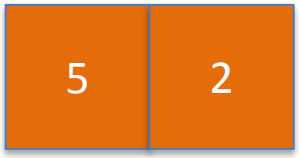
15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

S1



P1[pc]

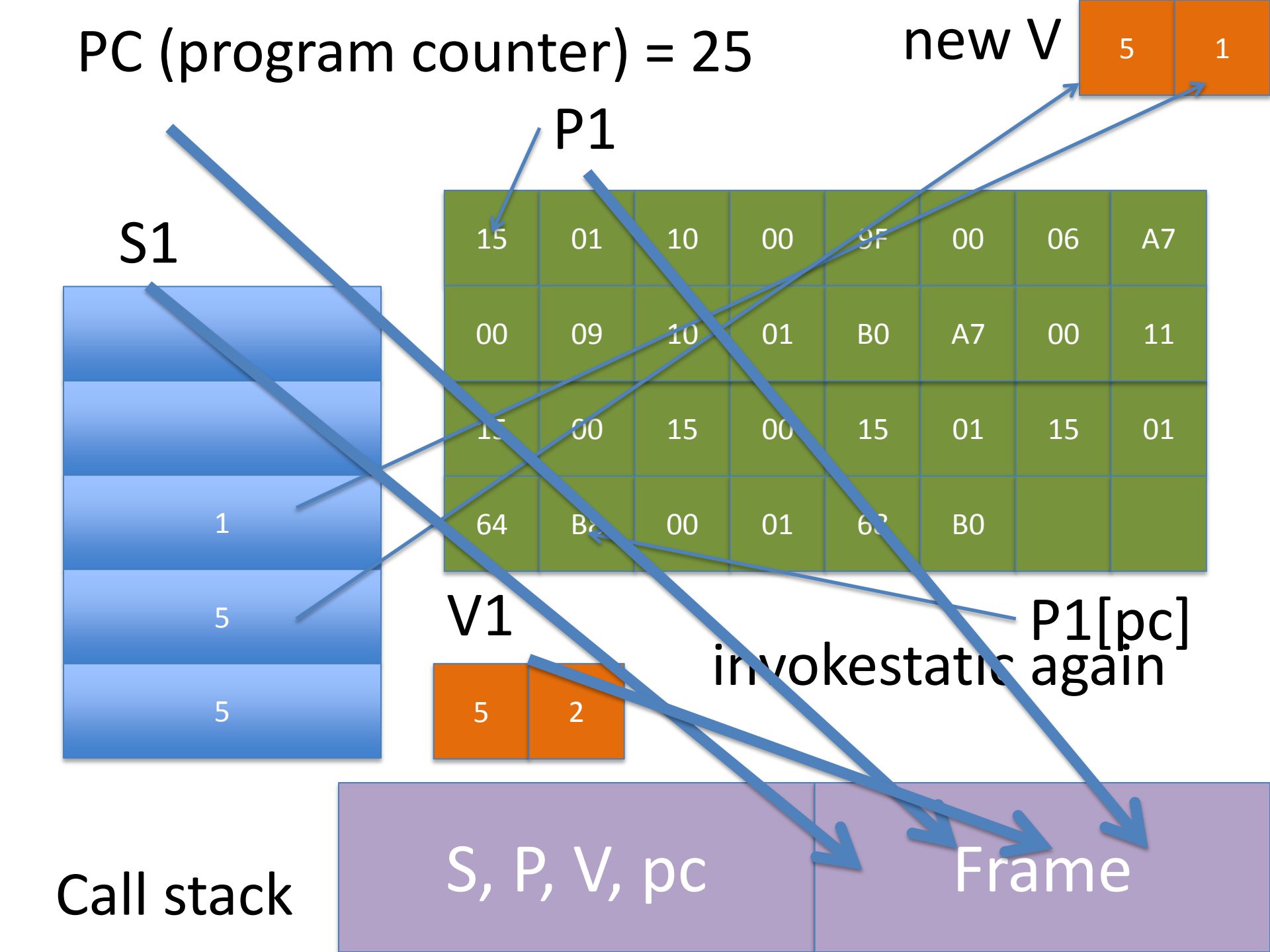
V1



after isub

Call stack

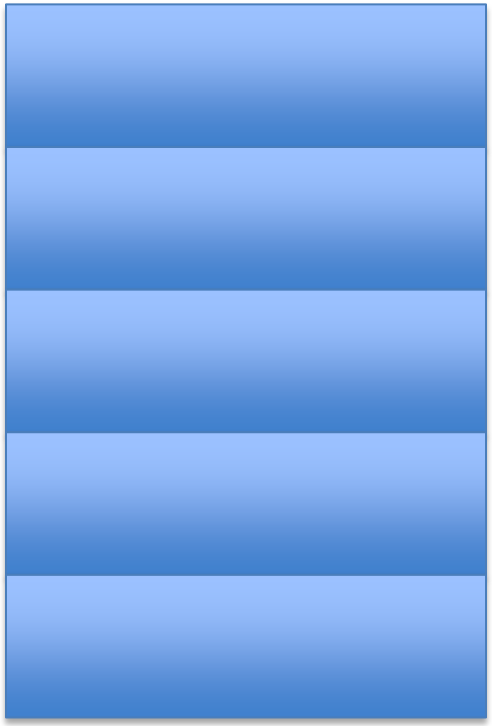
S, P, V, pc


PC (program counter) = 25
new V
5
1
P1
S1
15 01 10 00 9F 00 06 A7
00 09 10 01 B0 A7 00 11
00 15 00 15 01 15 01
64 00 01 B0
1
5
5
V1
5 2
P1[pc]
invokestatic again
Call stack
S, P, V, pc
Frame

PC (program counter) = 0

P2[pc]

S2



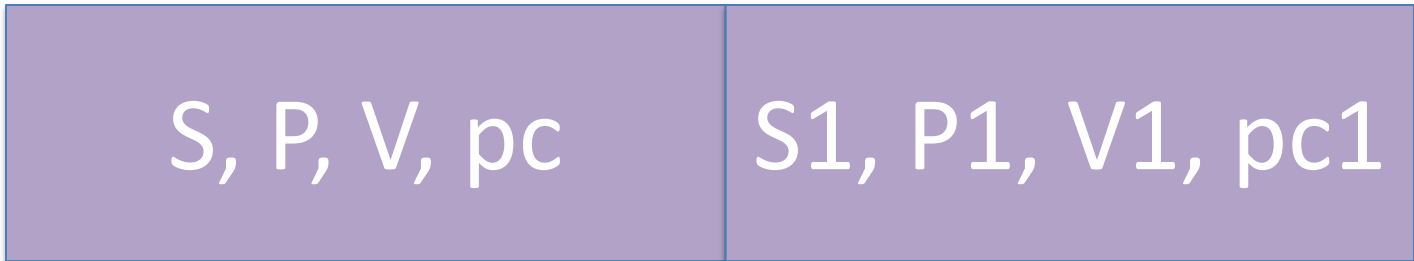
15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

V2

5	1

invokestatic again

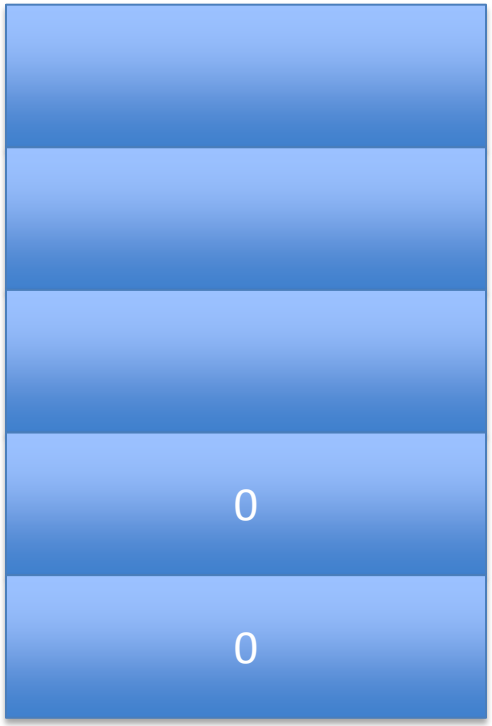
Call stack



Skip forward…

PC (program counter) = 4

S3



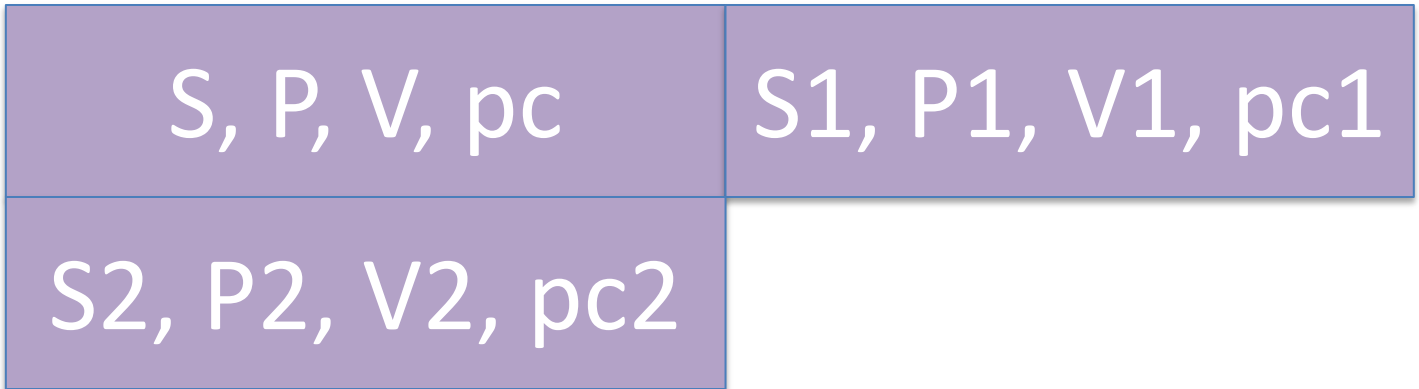
15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

P3[pc]

V3

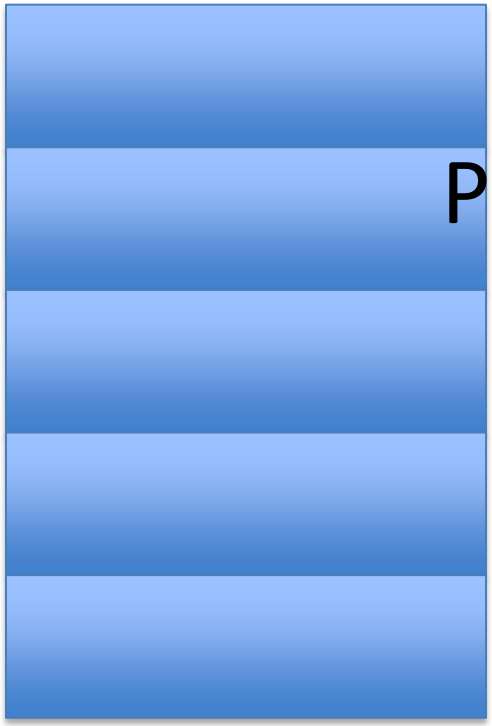
5	0

Call stack



PC (program counter) = 10

S3



P3[pc]

15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

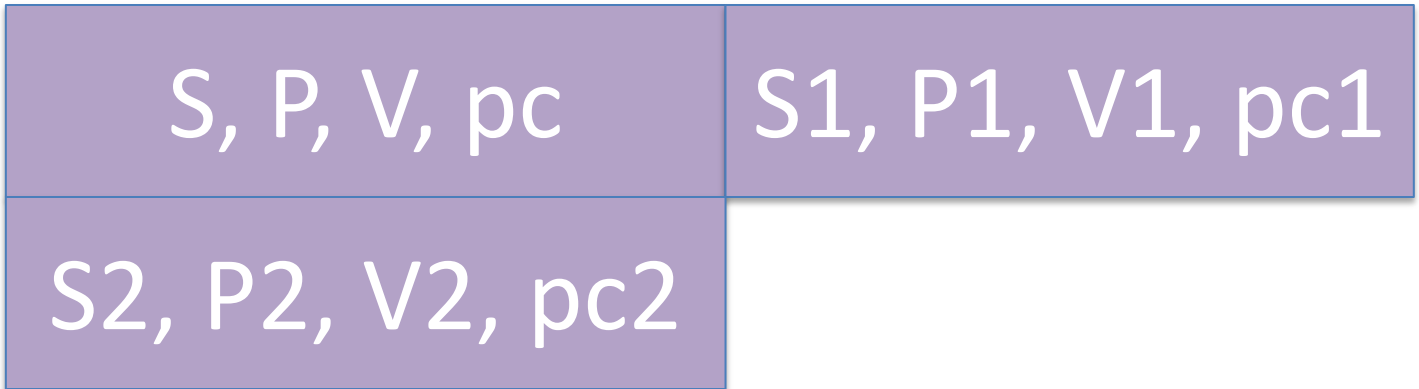
V3

5	0

after if_cmpeq +6-

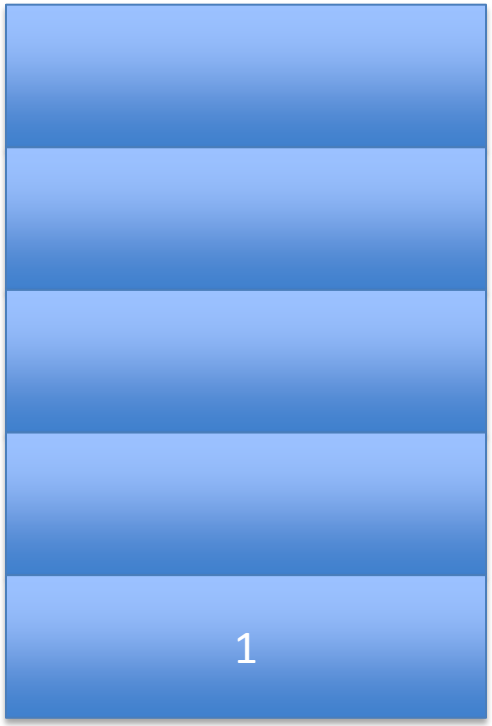
pop 2 off S, if =, +6

Call stack



PC (program counter) = 12

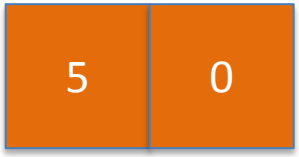
S3



15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

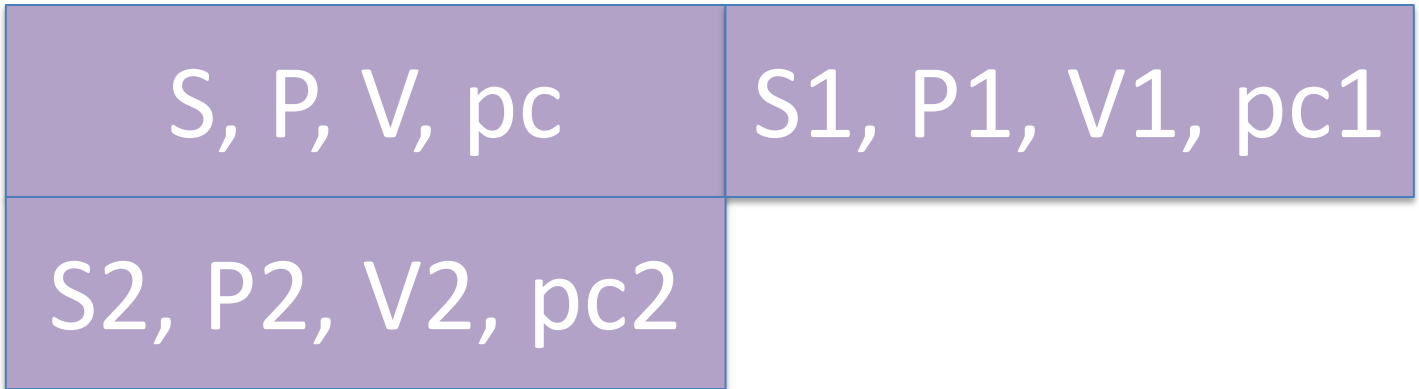
P3[pc]

V3



after bipush 1

Call stack

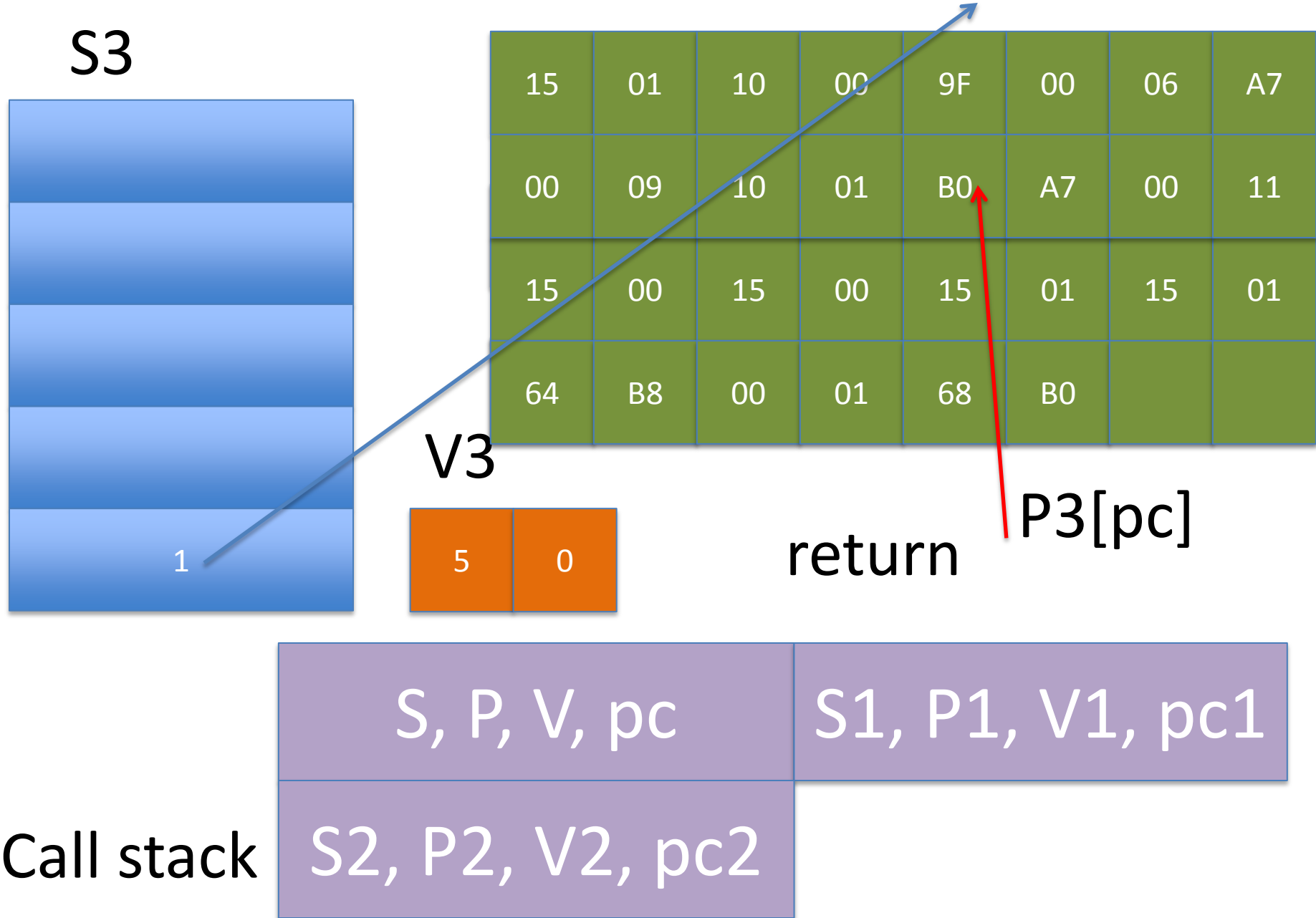


Now for the magic: return

- 3 things happen in return
- 1) return value is popped off the stack
- 2) the state space is restored using the top stack frame of the call stack (S = S2, P = P2…)
- 3) return value is pushed onto the new state space stack

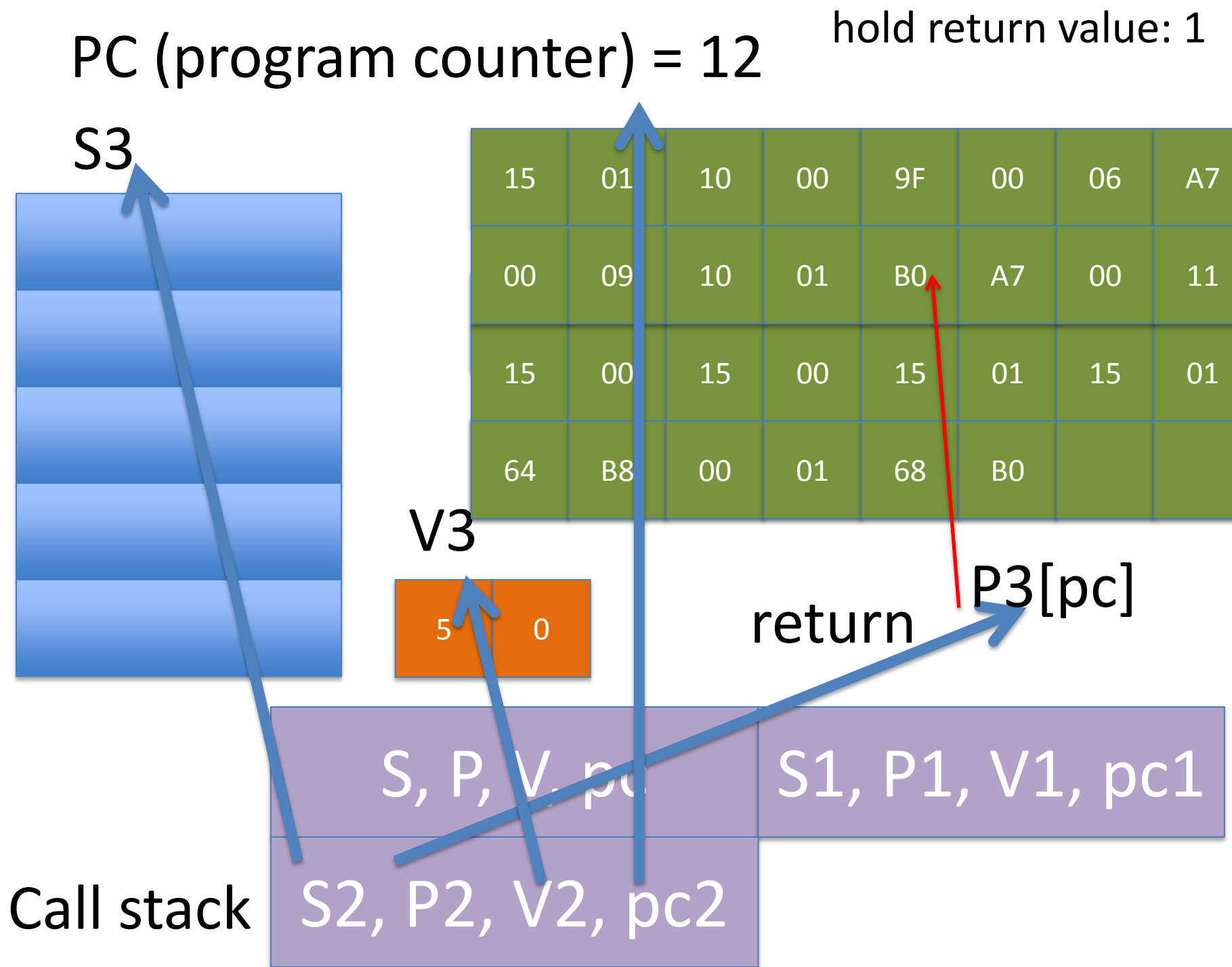
PC (program counter) = 12

hold return value: 1



Call stack

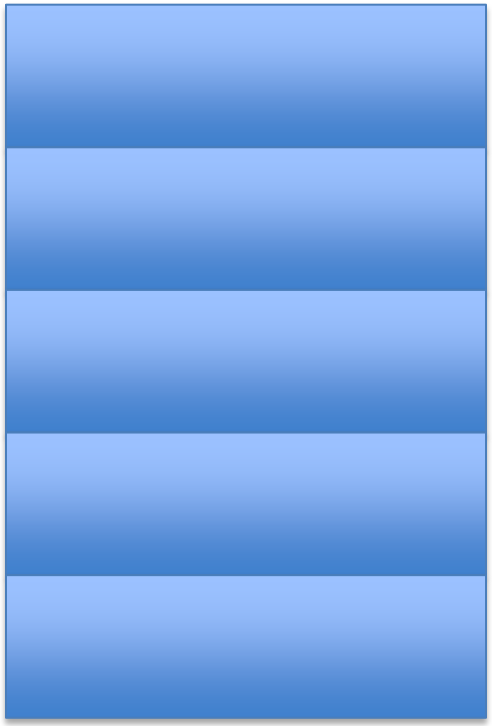
S, P, V, pc	S1, P1, V1, pc1
S2, P2, V2, pc2	


PC (program counter) = 12
hold return value: 1
S3
15 01 10 00 9F 00 06 A7
00 09 10 01 B0 A7 00 11
15 00 15 00 15 01 15 01
64 B8 00 01 68 B0
V3
5 0
P3[pc]
return
S, P, V, pc
S1, P1, V1, pc1
S2, P2, V2, pc2
Call stack

PC (program counter) = 28

hold return value: 1

S2



15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

V2

5	1

return

P2[pc]

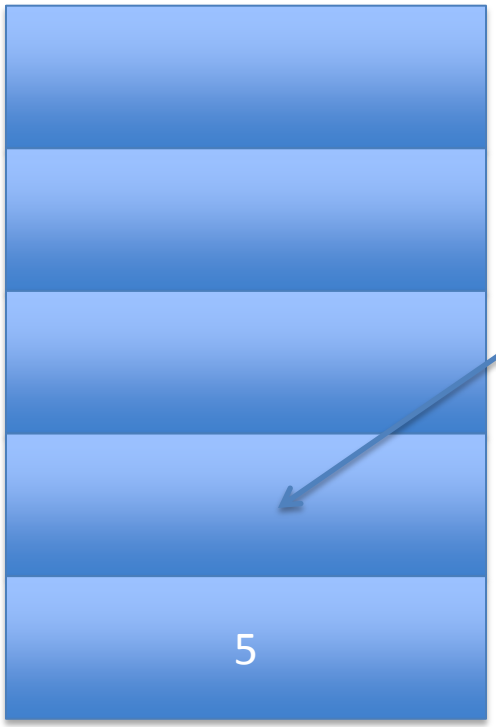
Call stack

S, P, V, pc	S1, P1, V1, pc1

PC (program counter) = 28

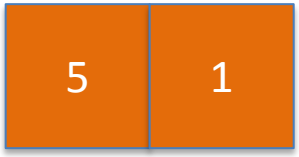
hold return value: 1

S2



15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

V2



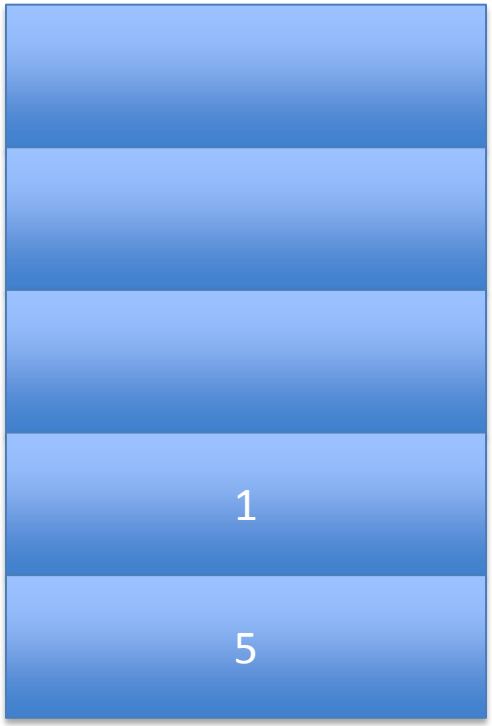
return

P2[pc]

Call stack

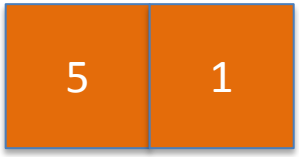
PC (program counter) = 28

S2



15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

V2



return

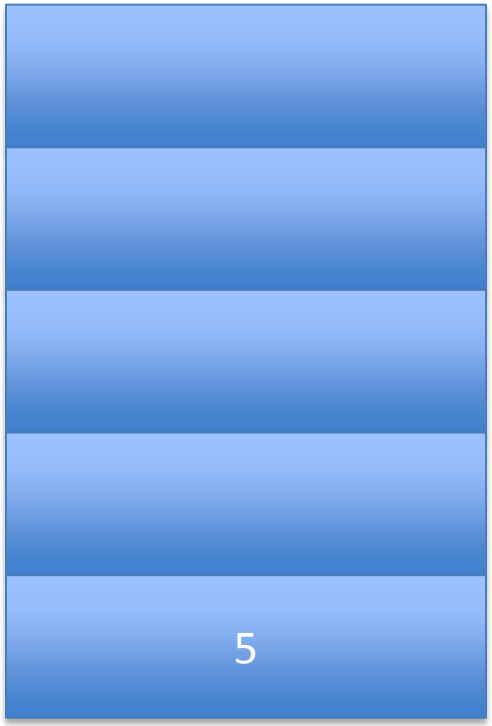
P2[pc]

Call stack

PC (program counter) = 29

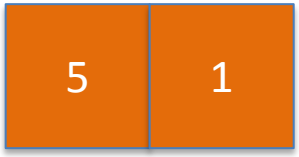
hold return value: 1

S2



15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

V2

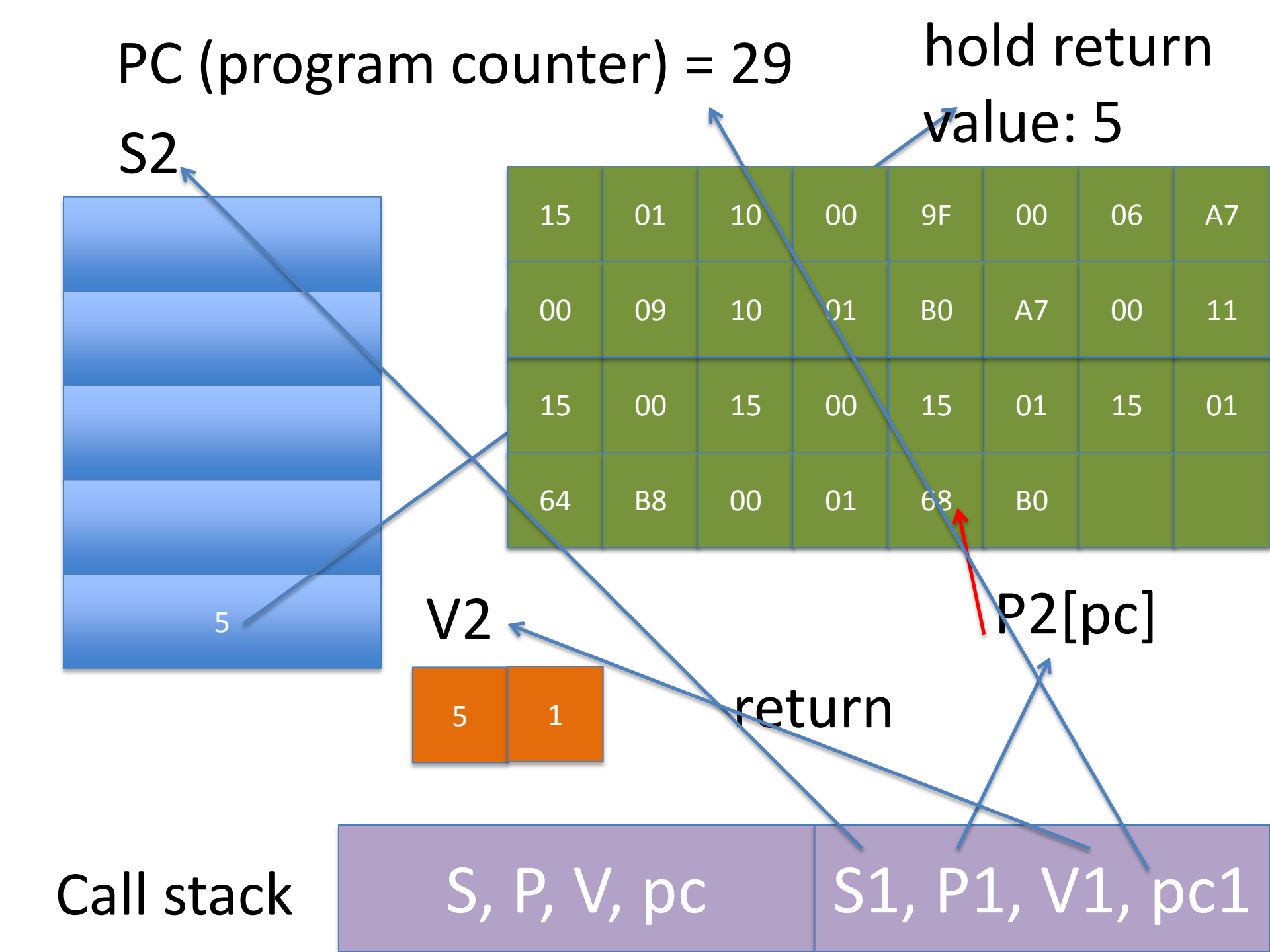


imul

P2[pc]

Call stack

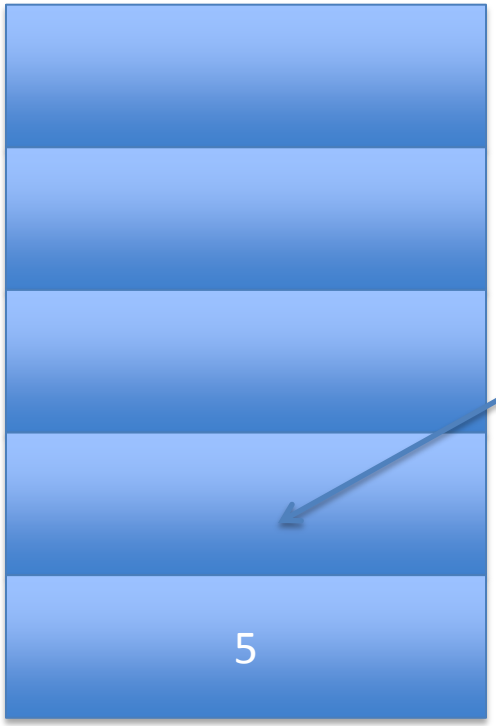
S, P, V, pc	S1, P1, V1, pc1


PC (program counter) = 29
hold return value: 5
S2
15 01 10 00 9F 00 06 A7
00 09 10 01 B0 A7 00 11
15 00 15 00 15 01 15 01
64 B8 00 01 68 B0
5
V2
5 1
P2[pc]
return
Call stack
S, P, V, pc
S1, P1, V1, pc1

PC (program counter) = 28

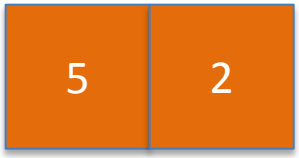
hold return value: 5

S1



15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

V1



return

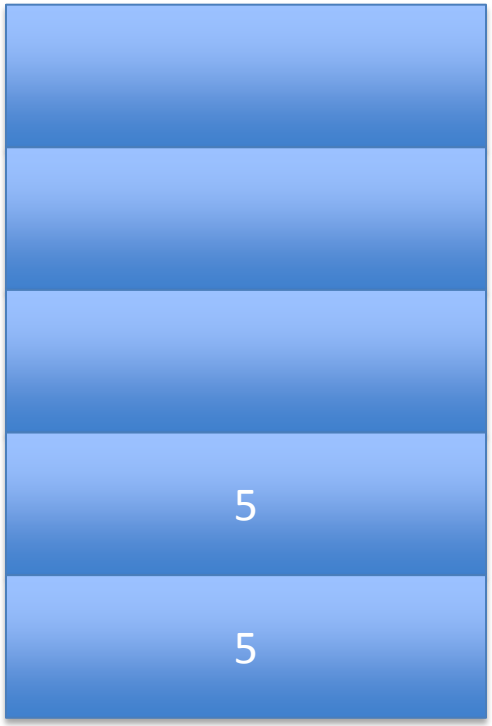
P1[pc]

Call stack

S, P, V, pc

PC (program counter) = 28

S1



15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

V1

return

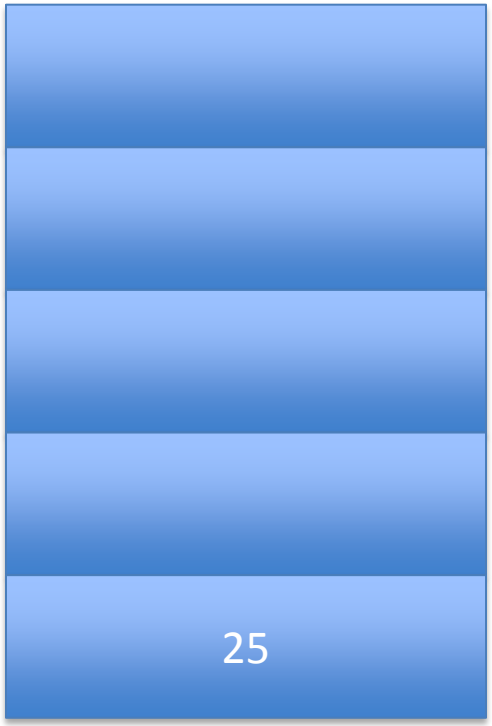
P1[pc]

Call stack

S, P, V, pc

PC (program counter) = 29

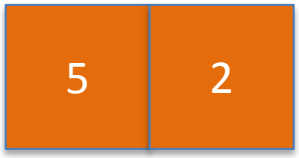
S1



15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

P1[pc]

V1



imul

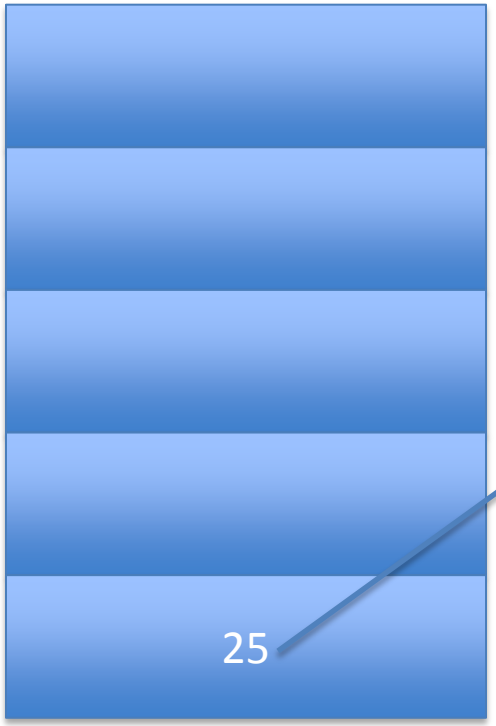
Call stack

S, P, V, pc

PC (program counter) = 29

hold return value: 25

S1



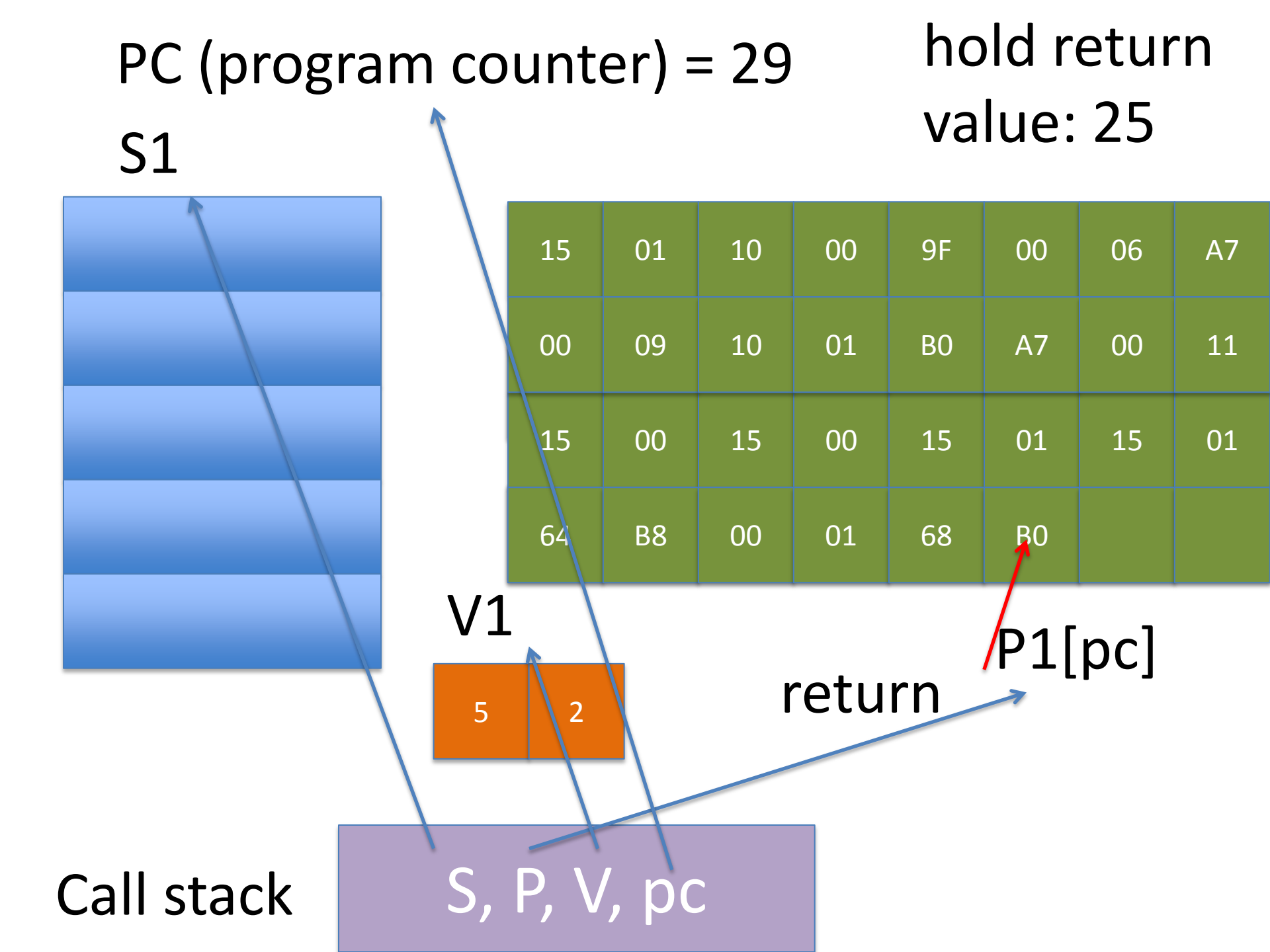
15	01	10	00	9F	00	06	A7
00	09	10	01	B0	A7	00	11
15	00	15	00	15	01	15	01
64	B8	00	01	68	B0		

V1

P1[pc]

Call stack

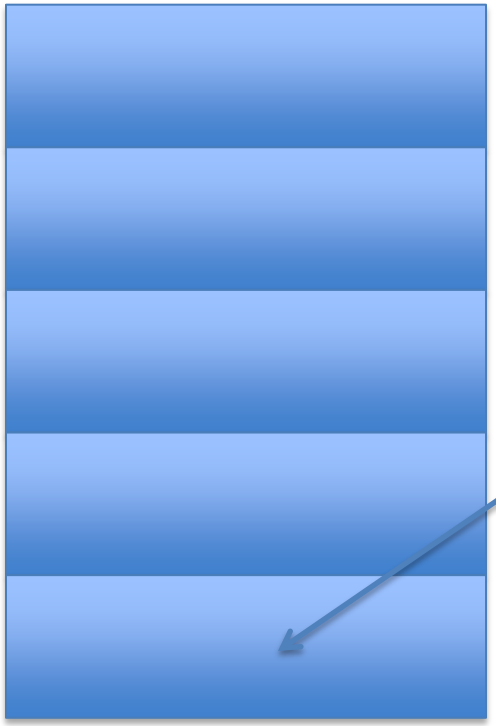
S, P, V, pc


PC (program counter) = 29
hold return value: 25
S1
15 01 10 00 9F 00 06 A7
00 09 10 01 B0 A7 00 11
15 00 15 00 15 01 15 01
64 B8 00 01 68 B0
V1
5 2
P1[pc]
return
Call stack
S, P, V, pc

PC (program counter) = 15

hold return value: 25

S



10	05	36	00	10	02	36	01

15	00	15	01	B8	00	01	36

V

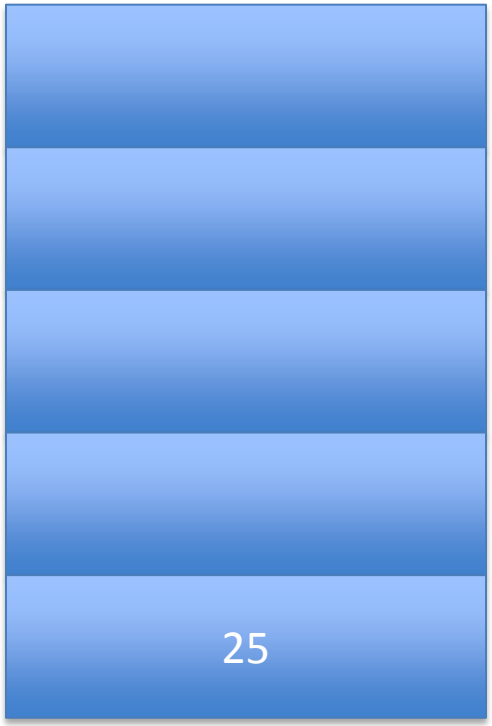
5	2	

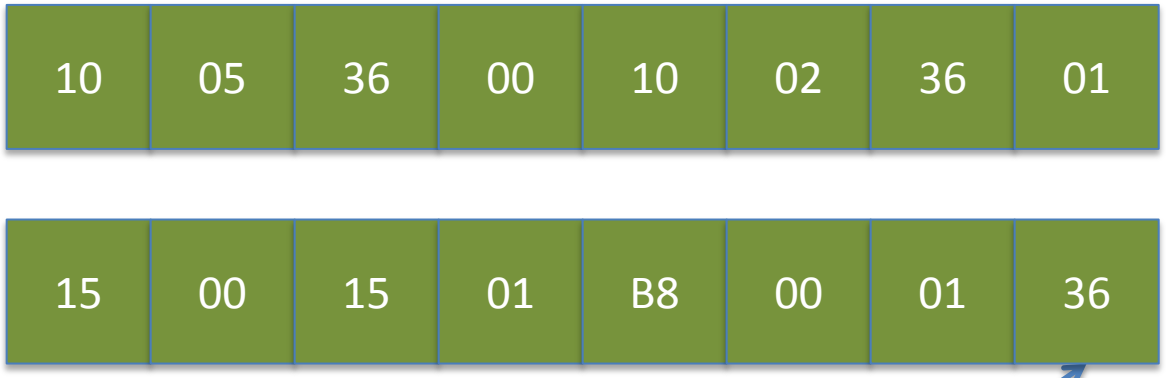
P[pc]

Call stack

PC (program counter) = 15

S





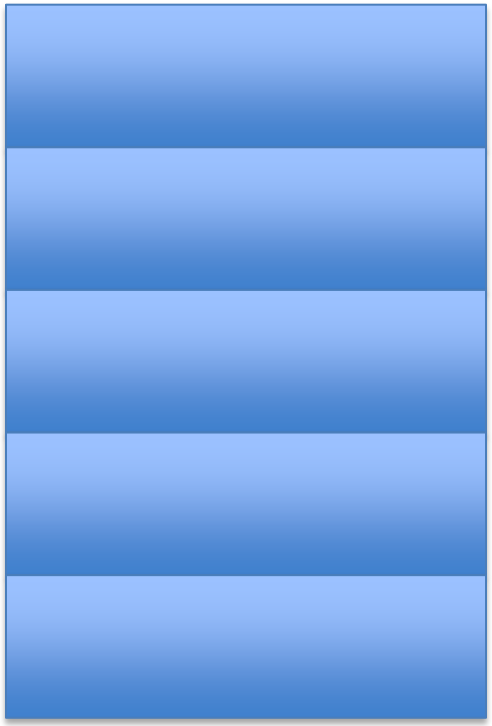
P[pc]

V

Call stack

PC (program counter) = 17

S



10	05	36	00	10	02	36	01
15	00	15	01	B8	00	01	36
02	15	02	B0				

V

5	2	

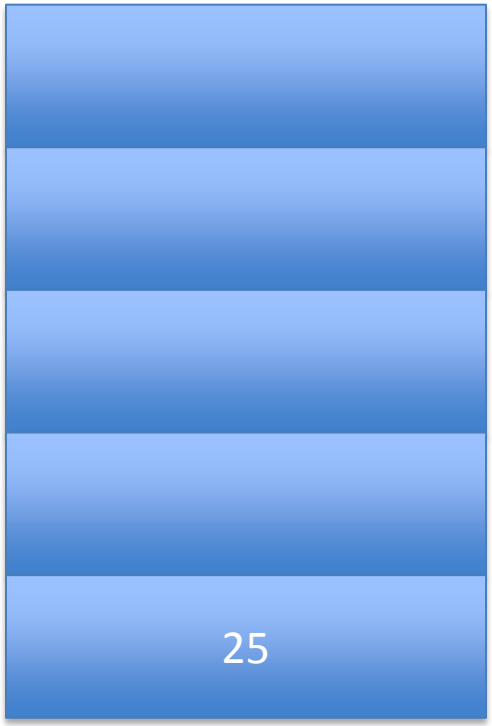
P[pc]

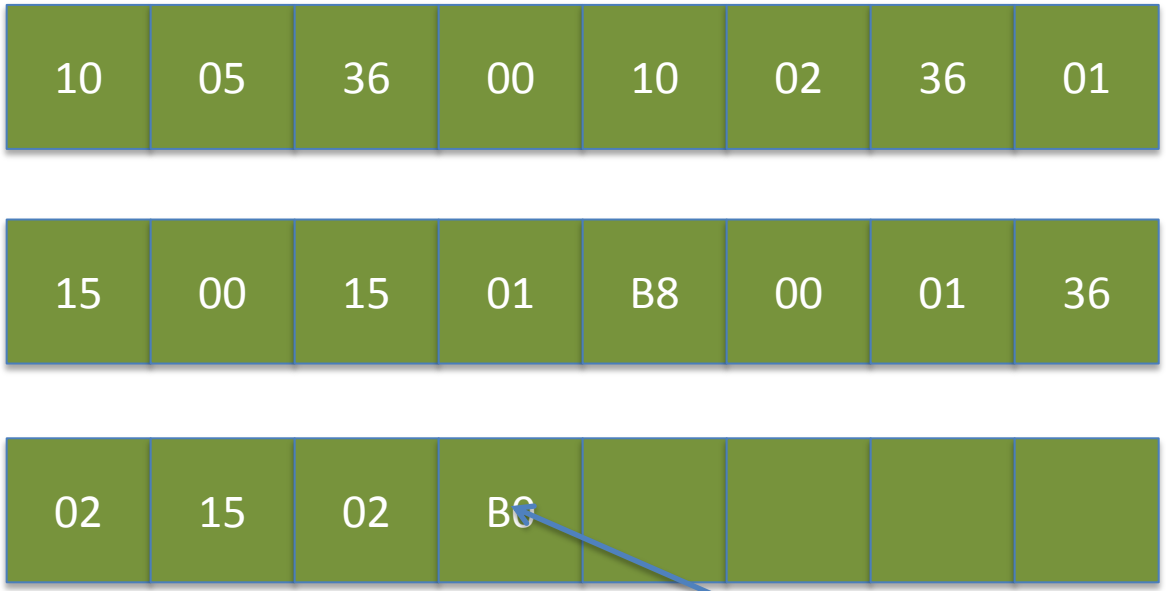
vstore 2

Call stack

PC (program counter) = 19

S





V

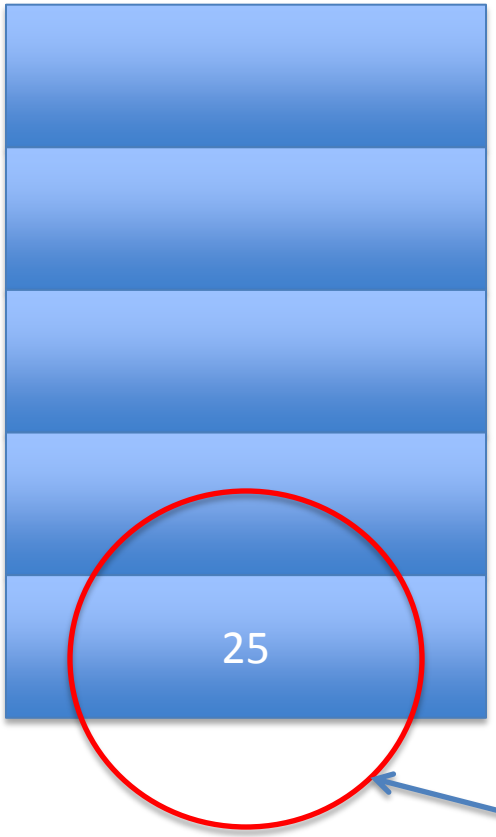
P[pc]

vload 2

Call stack

PC (program counter) = 19

S



10	05	36	00	10	02	36	01
15	00	15	01	B8	00	01	36
02	15	02	B8				

P[pc]

V

5	2	25

return

on return from main, the top of the stack is our final answer

Call stack