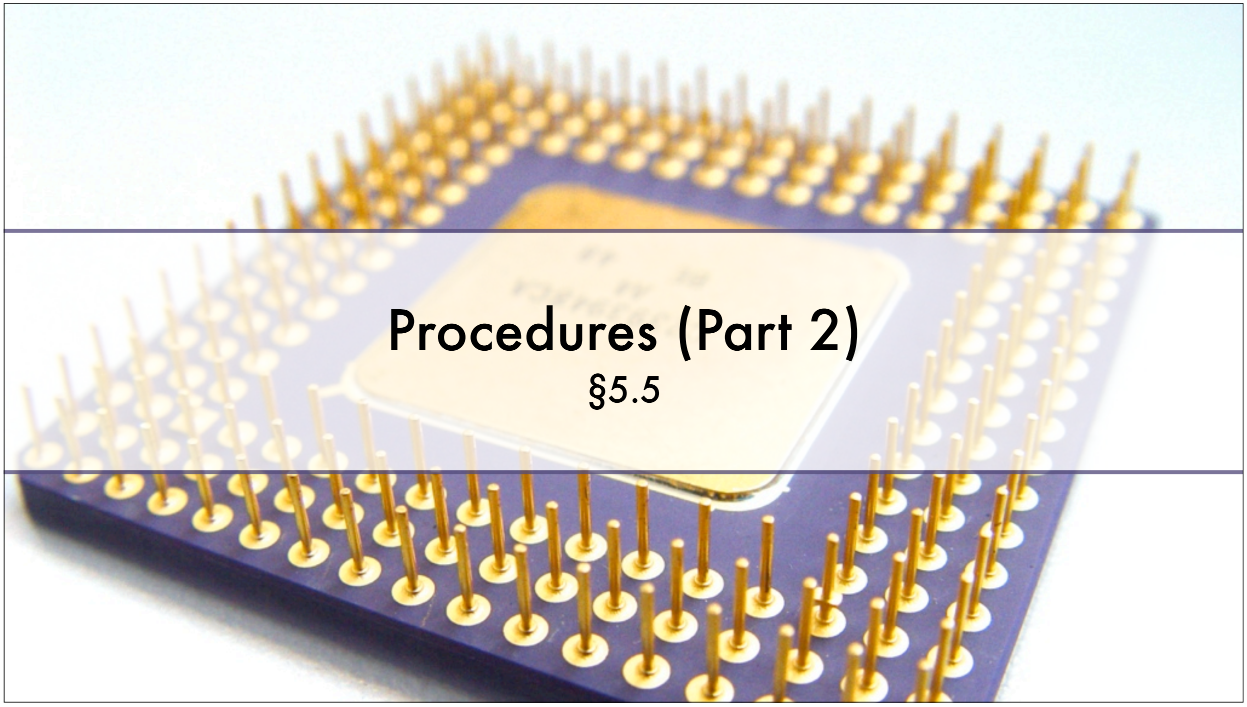


Procedures (Part 2)

§5.5

One Way to Implement a Stack

- `array DWORD 256 DUP(?)`
- `top_address DWORD (OFFSET array + SIZEOF array)`

- *Push (push 32-bit value in EAX onto stack):*
  - `sub top_address, 4` *; Stack grows downward in memory!*
  - `mov esi, top_address`
  - `mov [esi], eax`

- *Pop (remove 32-bit top element, return in EAX):*
  - `mov esi, top_address`
  - `mov eax, [esi]`
  - `add top_address, 4` *; Omit this to implement Top*

This is essentially how the runtime stack works

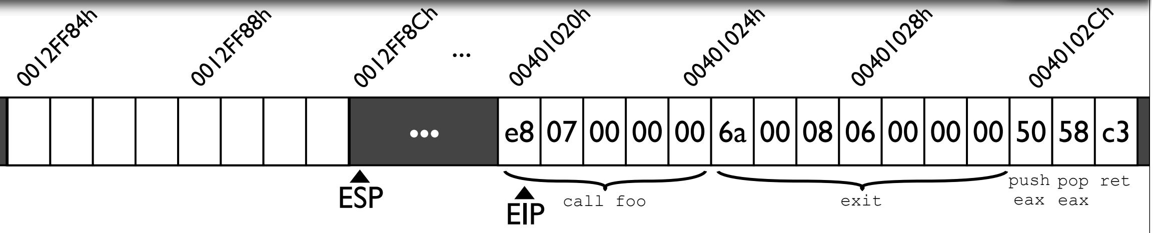
(but the top address is stored in ESP)

Topics Covered in Notes:

- PUSH instruction
- POP instruction
- CALL instruction
- RET instruction

Recall: Runtime Stack – How It's Used

Before call:



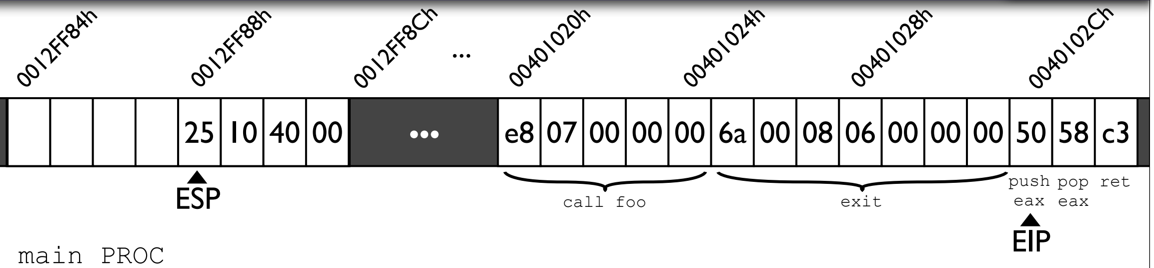
```
   main PROC
⇨      call foo
       exit
   main ENDP

   foo PROC
       push eax
       pop eax
       ret
   foo ENDP
```

- The `call` instruction will
  - Decrease ESP by 4
  - Store the address of the instruction *following* `call` at the memory address now in ESP
  - Set EIP to the memory address of the first instruction in the called procedure

Recall: Runtime Stack – How It's Used

After call:



0012FF84h 0012FF88h 0012FF8Ch … 00401020h 00401024h 00401028h 0040102Ch

| | | | | 25 | 10 | 40 | 00 | ••• | e8 | 07 | 00 | 00 | 00 | 6a | 00 | 08 | 06 | 00 | 00 | 00 | 50 | 58 | c3 |

ESP

call foo exit push eax pop eax ret

EIP

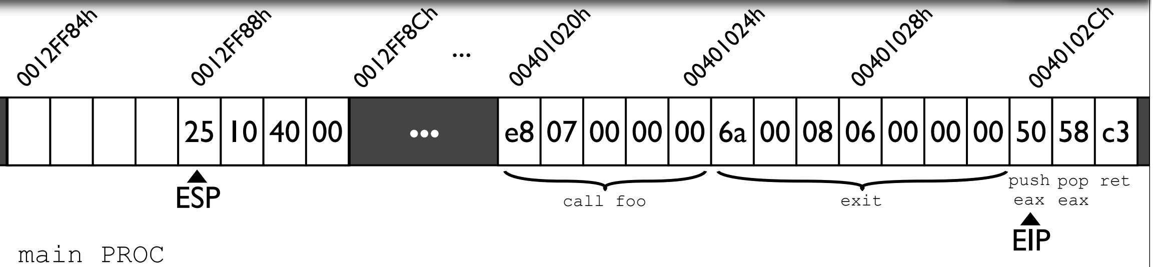
```
main PROC
    call foo
    exit
main ENDP

foo PROC
    push eax
    pop eax
    ret
foo ENDP
```

- The `call` instruction
  - Decrease ESP by 4
  - Store the address of the instruction *following* `call` at the memory address now in ESP
  - Set EIP to the memory address of the first instruction in the called procedure

Recall: Runtime Stack – How It's Used

Before push:



0012FF84h 0012FF88h 0012FF8Ch … 00401020h 00401024h 00401028h 0040102Ch

| | | | | 25 | 10 | 40 | 00 | ••• | e8 | 07 | 00 | 00 | 00 | 6a | 00 | 08 | 06 | 00 | 00 | 00 | 50 | 58 | c3 |

ESP

call foo exit push eax pop eax ret

EIP

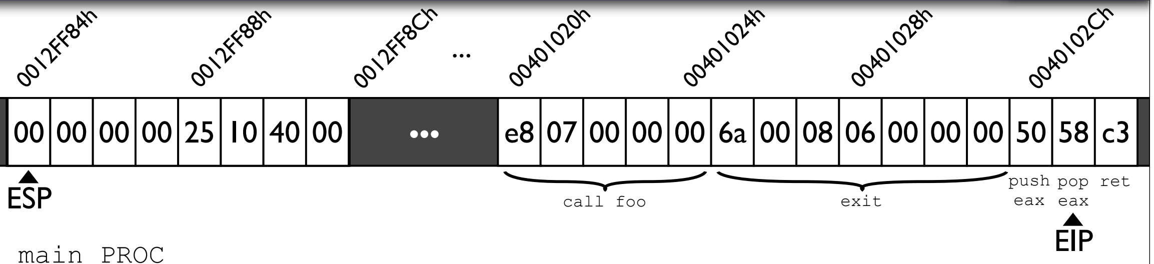
```
main PROC
    call foo
    exit
main ENDP

foo PROC
    push eax
    pop eax
    ret
foo ENDP
```

- The `push` instruction will
  - Decrease ESP by 4
  - Store the value indicated at the address in ESP (we'll assume EAX contains 00000000h)

Recall: Runtime Stack – How It's Used

After push:



```
0012FF84h        0012FF88h        0012FF8Ch  …   00401020h        00401024h        00401028h        0040102Ch
00 00 00 00 25 10 40 00  •••  e8 07 00 00 00 6a 00 08 06 00 00 00 50 58 c3
ESP                           call foo         exit                push pop ret
                                                                   eax  eax
                                                                   EIP
```

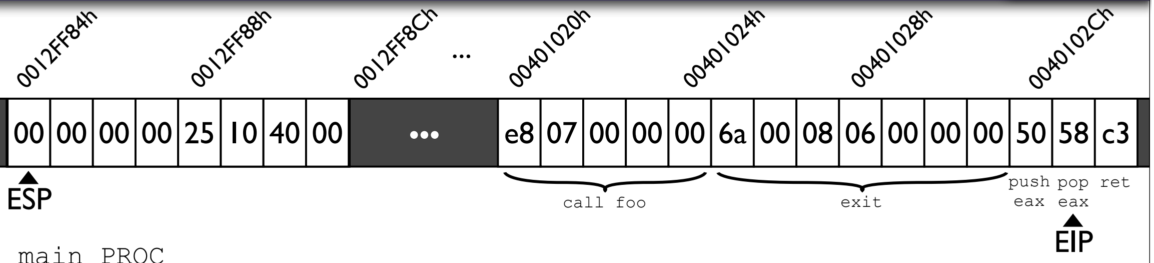
```
main PROC
     call foo
     exit
main ENDP

foo PROC
     push eax
⇨    pop eax
     ret
foo ENDP
```

- The push instruction will
  - Decrease ESP by 4
  - Store the value indicated at the address in ESP (we'll assume EAX contains 00000000h)

Recall: Runtime Stack – How It's Used

Before pop:

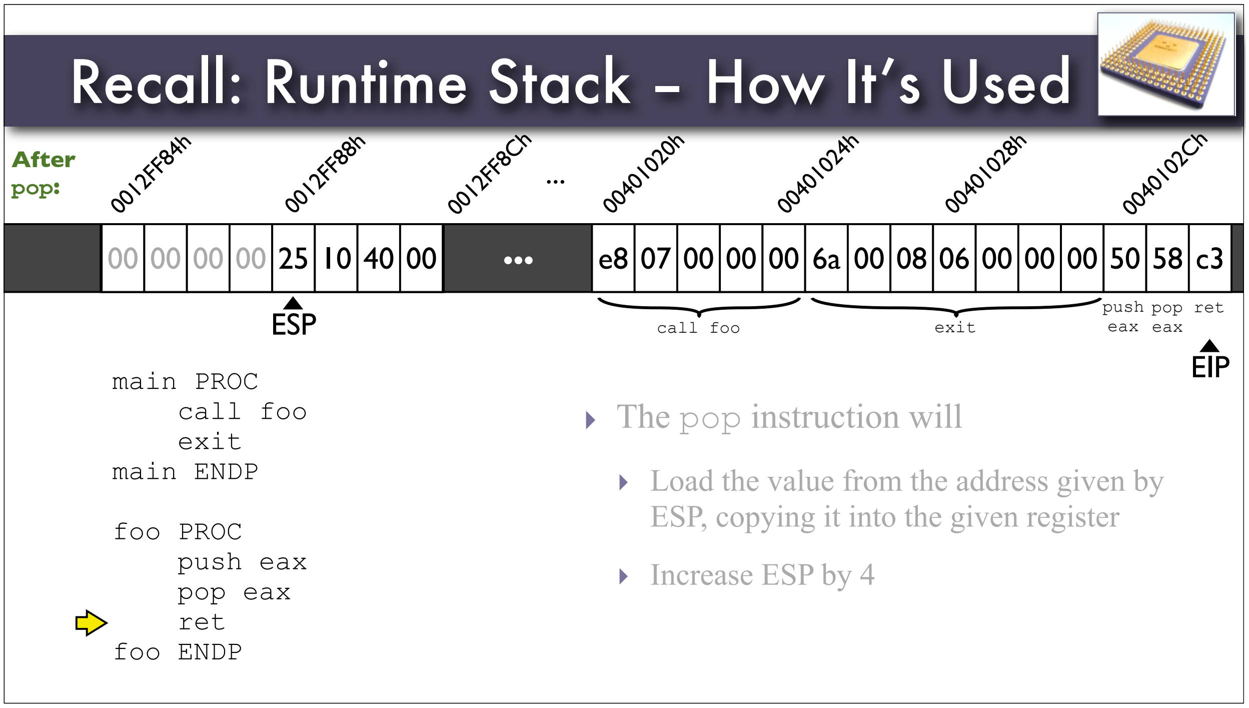


```
0012FF84h        0012FF88h        0012FF8Ch  …   00401020h        00401024h        00401028h        0040102Ch
00 00 00 00 25 10 40 00  •••  e8 07 00 00 00 6a 00 08 06 00 00 00 50 58 c3
ESP                           call foo         exit                push pop ret
                                                                   eax  eax
                                                                   EIP
```

```
main PROC
     call foo
     exit
main ENDP

foo PROC
     push eax
⇨    pop eax
     ret
foo ENDP
```

- The pop instruction will
  - Load the value from the address given by ESP, copying it into the given register
  - Increase ESP by 4



Recall: Runtime Stack – How It's Used

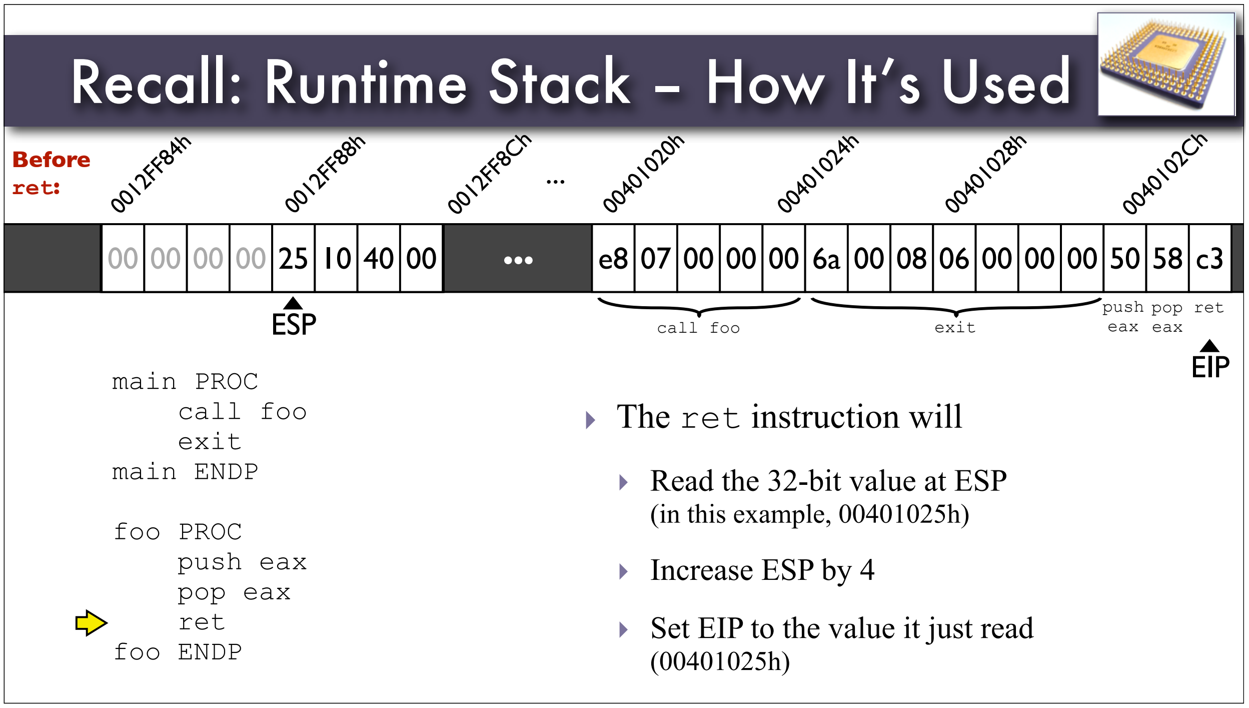
After pop:

0012FF84h				0012FF88h				0012FF8Ch …	00401020h				00401024h				00401028h				0040102Ch		
00	00	00	00	25	10	40	00	•••	e8	07	00	00	00	6a	00	08	06	00	00	00	50	58	c3
				ESP					call foo					exit							push eax	pop eax	ret EIP

```
     main PROC
          call foo
          exit
     main ENDP

     foo PROC
          push eax
          pop eax
⇨         ret
     foo ENDP
```

- The `pop` instruction will
  - Load the value from the address given by ESP, copying it into the given register
  - Increase ESP by 4



Recall: Runtime Stack – How It's Used

Before ret:

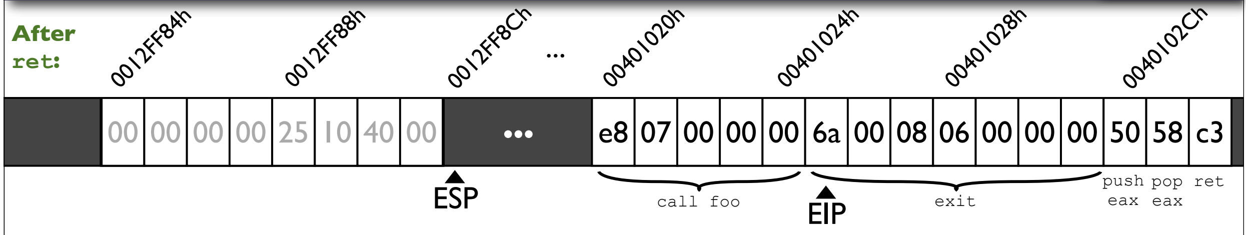
0012FF84h				0012FF88h				0012FF8Ch …	00401020h				00401024h				00401028h				0040102Ch		
00	00	00	00	25	10	40	00	•••	e8	07	00	00	00	6a	00	08	06	00	00	00	50	58	c3
				ESP					call foo					exit							push eax	pop eax	ret EIP

```
     main PROC
          call foo
          exit
     main ENDP

     foo PROC
          push eax
          pop eax
⇨         ret
     foo ENDP
```

- The `ret` instruction will
  - Read the 32-bit value at ESP (in this example, 00401025h)
  - Increase ESP by 4
  - Set EIP to the value it just read (00401025h)

Recall: Runtime Stack – How It's Used

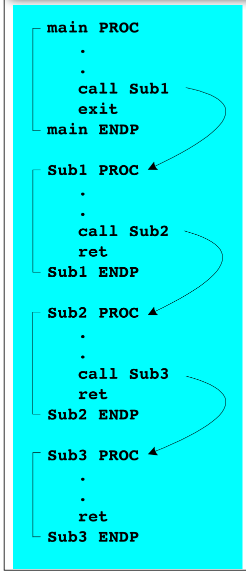


```
     main PROC
         call foo
➪        exit
     main ENDP

     foo PROC
         push eax
         pop eax
         ret
     foo ENDP
```

- The `ret` instruction will
  - Read the 32-bit value at ESP (in this example, 00401025h)
  - Increase ESP by 4
  - Set EIP to the value it just read (00401025h)

Nested Procedure Calls



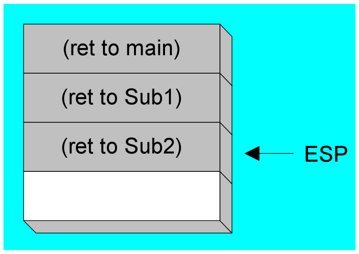
```
main PROC
    .
    .
    call Sub1
    exit
main ENDP

Sub1 PROC
    .
    .
    call Sub2
    ret
Sub1 ENDP

Sub2 PROC
    .
    .
    call Sub3
    ret
Sub2 ENDP

Sub3 PROC
    .
    .
    ret
Sub3 ENDP
```

- *Nested procedure calls:* you call a procedure, and it calls other procedures before returning to you
- main calls Sub1
  Sub1 calls Sub2
  Sub2 calls Sub3



- Recall: Stacks are last-in-first-out (LIFO) data structures
- You always want to return to the *last* procedure that CALLed
- The last procedure that CALLed will be the first address POPped

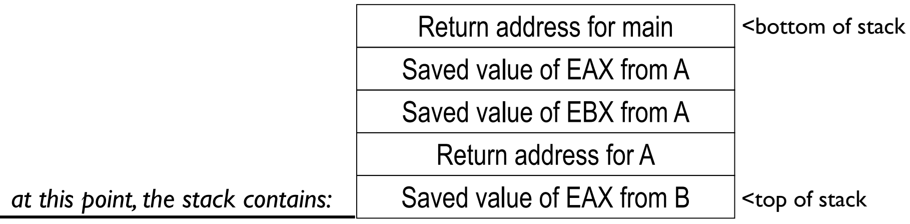
Irvine, Kip R. Assembly Language for x86 Processors 6/e, 2010.

Nested Procedure Calls

```
main PROC
    call A
    exit
main ENDP

A PROC
    push eax
    push ebx
    call B
    pop ebx
    pop eax
    ret
A ENDP

B PROC
    push eax
    pop eax
    ret
B ENDP
```



at this point, the stack contains:

Return address for main <bottom of stack

Saved value of EAX from A

Saved value of EBX from A

Return address for A

Saved value of EAX from B <top of stack