NASM: data and bss Beyond the screencast

ICS312

Machine-Level and Systems Programming

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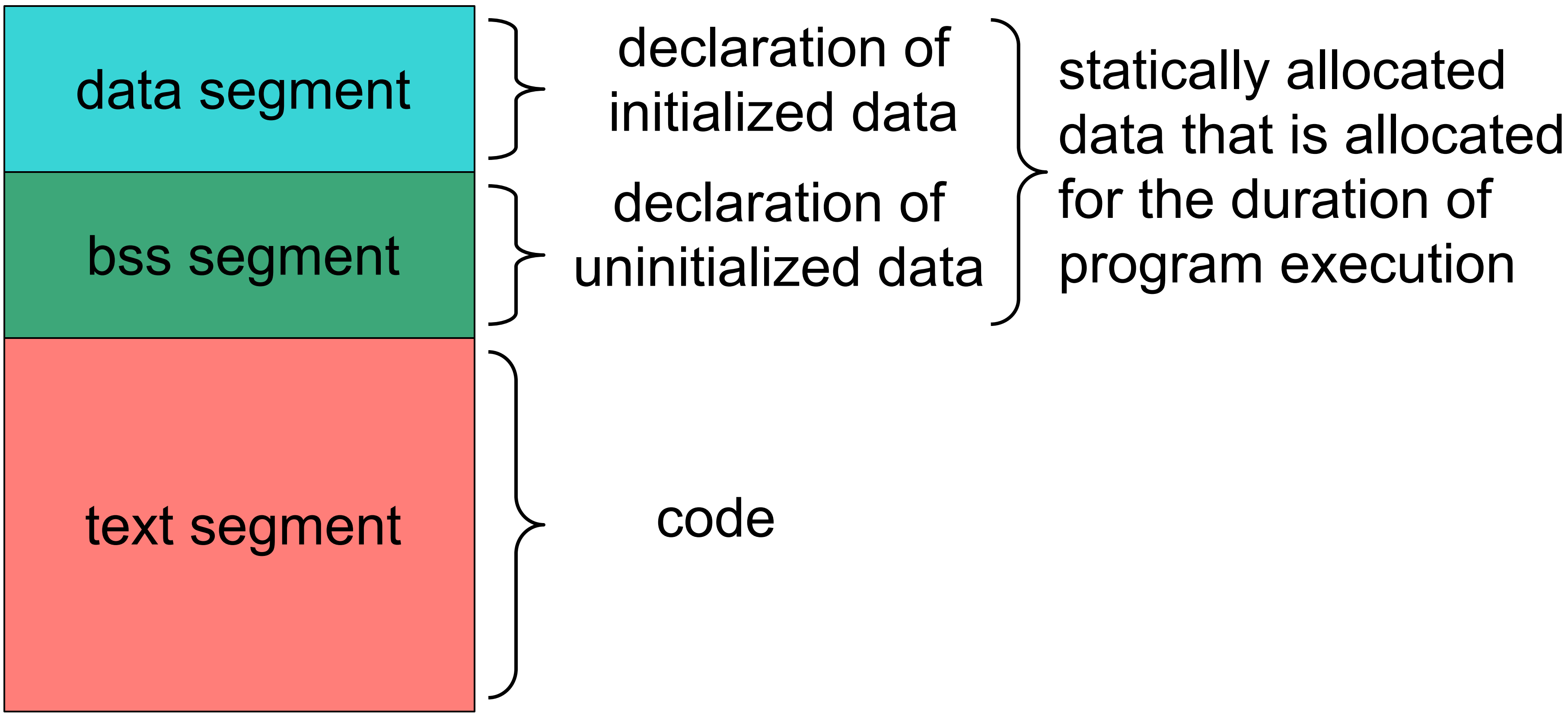
NASM Program Structure



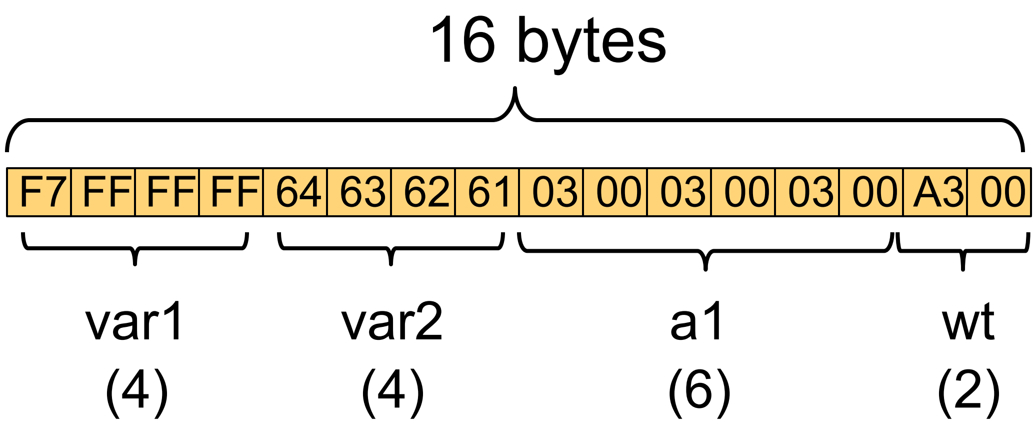
Practice #1

```
var1        dd     -9
var2        db     "dcba"
a1          times 3      dw     011b
wt          db     0A3h, 0
```

- What is the layout and the content of the data memory segment on a LITTLE ENDIAN machine?
  - Byte per byte, in hex

Practice #1

```
var1        dd     -9
var2        db     "dcba"
a1          times 3      dw     011b
wt          db     0A3h, 0
```



Practice #2

```
x1          dw     -22
msg         db     "ba", 0
array       times 2      dd     023o
wt          dw     0,011b,020o
```

- What is the layout and the content of the data memory segment on a BIG ENDIAN machine?
  - Byte per byte, in hex

Practice #2

```
x1          dw     -22
msg         db     "ba", 0
array       times 2     dd     023o
wt          dw     0,011b,020o
```

19 bytes

FF	EA	62	61	00	00	00	00	13	00	00	00	13	00	00	00	03	00	10

x1 (2) msg (3) array (8) wt (6)

More practice?

- Of course we can easily come up with tones of practice examples…
- Should we do one more right now?

Homework Assignment #2

- Homework Assignment #2 is posted
- With what we’ve seen you can get started on Exercise #1
- For Exercise #2 we need to go further a bit…
    - We might do it all today

Our first instructions

- At this point we need to introduce a few assembly instructions
  - adding integers
  - subtracting integers
  - moving data between registers / memory locations / constants

Different kinds of operands

- Assembly instructions can have operands, and it's important to know what kind of operands are possible
- Register: specifies one of the registers
  - **add eax, ebx**
  - means eax = eax + ebx
- Memory: specifies an address in memory.
  - **add eax, [ebx]**
  - means eax = eax + content (4 bytes) of memory at address ebx
- Immediate: specifies a fixed value (i.e., a number)
  - **add eax, 2**
  - means eax = eax + 2
- Implied: not actually encoded in the instruction
  - **inc eax**
  - means eax = eax + 1

Additions, subtractions

- Additions
  - add eax, 4 ; eax = eax + 4
  - add al, ah ; al = al + ah
- Subtractions
  - sub bx, 10 ; bx = bx - 10
  - sub ebx, edi ; ebx = ebx - edi
- Increment, Decrement
  - inc ecx ; ecx++ (a 4-byte operation)
  - dec dl ; dl-- (a 1-byte operation)

The move instruction

- This instruction moves data from one location to another

  mov **dest**, **src**
- Destination goes first, and the source goes second
- At most one of the operands can be a memory operand
  - mov eax, [ebx] ; **OK**
  - mov [eax], ebx ; **OK**
  - mov [eax], [ebx] ; **NOT OK**
- Both operands must be exactly the same size
  - For instance, AX cannot be stored into BL
- Examples:
  - mov ax, ebx ; **NOT OK**
  - mov bx, ax ; **OK**
- This type of “exceptions to the common case” make programming languages difficult to learn and assembly may be the worst offender
  - By contrast, Lisp is known for being very consistent (ICS313)

Use of Labels

- It is important to constantly be aware that when using a label in a program, the label is a pointer, not a value
- Therefore, a common use of the label in the code is as a memory operand, in between square brackets **'[' ']'**
- mov AL, [L1]
  - Copy the 1-byte value at address L1 into register AL
- Question: how does the assembler know how many bits to move?
- Answer: it's up to the programmer to do the right thing, that is load into appropriately sized registers
  - In the above example, since AL is a 1-byte register, then 1 byte is moved
- LABELS HAVE NO TYPE!
  - So although it's tempting to think of them as variables, they are much more limited: just pointers to a byte somewhere

Moving to/from a register

- Say we have the following data segment

  L db 0F0h, 0F1h, 0F2h, 0F3h

- Example: mov AL, [L]
  - Will copy 1 byte from memory into AL
- Example: mov AX, [L]
  - Will copy the 2 bytes from memory into AX
- Example: mov EAX, [L]
  - Will copy the 4 bytes from memory into EAX

- What bytes are written where depends on Little vs. Big Endian…

Mov and Little Endian

- Consider the following data segment

```
L1    db    0AAh, 0BBh, 0CCh, 0DDh
L2    dd    0AABBCCDDh
```

- The instruction: mov eax, [L1]

  puts DDCCBBAA into eax
  - Note that we’re loading 4x1 bytes as a 4-byte quantity
- The instruction: mov eax, [L2]

  puts AABBCCDD into eax!!!
  - Meaning that the memory content was DDCCBBAA
- When declaring a value in the data segment, that value is declared as it would be appearing in registers when loaded “whole”
  - It would be confusing to write numbers in little endian in the program
  - So all numerical values you write are in register-order not memory-order

Example

- Data segment (little endian):

```
L1      db      0AAh, 0BBh
L2      dw      0CCDDh
L3      db      0EEh, 0FFh
```

- Program:

```
mov eax, [L2]
mov ax, [L3]
mov [L1], eax
```

- What’s the final memory content?

Solution

- Data segment:

```
L1    db    0AAh, 0BBh
L2    dw    0CCDDh
L3    db    0EEh, 0FFh
```

L1		L2		L3	
AA	BB	DD	CC	EE	FF

Solution

L1		L2		L3	
AA	BB	DD	CC	EE	FF

mov eax, [L2] ; eax = FF EE CC DD

mov ax, [L3] ; eax = FF EE FF EE

mov [L1], eax ; content at L1 is EE FF EE FF

L1		L2		L3	
EE	FF	EE	FF	EE	FF

Final memory content

Moving immediate values

- Consider the instruction: mov [L], 1
- The assembler will give us an error: “operation size not specified”!
- This is because the assembler has no idea whether we mean for “1” to be 001h, 00001h, 000000001h, etc.
  - Labels have no type (they’re NOT variables)
- Therefore the assembler must provide us with a way to specify the size of immediate operands
- mov dword [L], 1
  - 4-byte double-word
- Size specifiers: byte, word, dword, qword (and tword)

Size Specifier Examples

mov	[L1], 1	; Error
mov	**byte** [L1], 1	; 1 byte
mov	**word** [L1], 1	; 2 bytes
mov	**dword** [L1], 1	; 4 bytes
mov	[L1], eax	; 4 bytes
mov	[L1], ax	; 2 bytes
mov	[L1], al	; 1 byte
mov	eax, [L1]	; 4 bytes
mov	ax, [L1]	; 2 bytes
mov	ax, 12	; 2 bytes

Brackets or no Brackets

- mov eax, [L]
  - Puts the content at address L into eax
  - Puts 32 bits of content, because eax is a 32-bit register
- mov eax, L
  - Puts the address L into eax
  - Puts the 32-bit address L into eax
- mov ebx, [eax]
  - Puts the content at address eax (= L) into ebx
- inc eax
  - Increase eax by one
- mov ebx, [eax]
  - Puts the content at address eax (= L + 1) into ebx

Example

```
first       db    00h, 04Fh, 012h, 0A4h
second      dw    165
third       db    "adf"
```

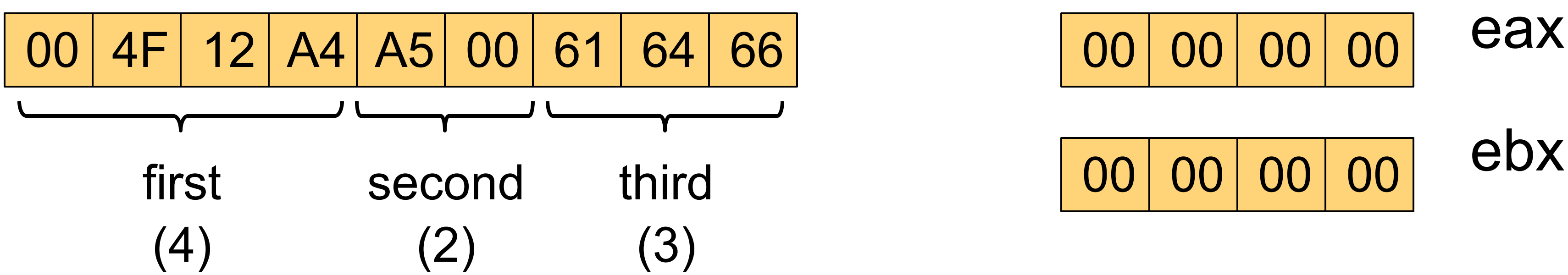
```
mov   eax, first
inc   eax
mov   ebx, [eax]
mov   [second], ebx
mov   byte [third], 11o
```

What is the content of the data segment after the code executes on a **Little Endian** Machine?

Example

```
first       db    00h, 04Fh, 012h, 0A4h
second      dw    165
third       db    "adf"
```

```
mov   eax, first
inc   eax
mov   ebx, [eax]
mov   [second], ebx
mov   byte [third], 11o
```

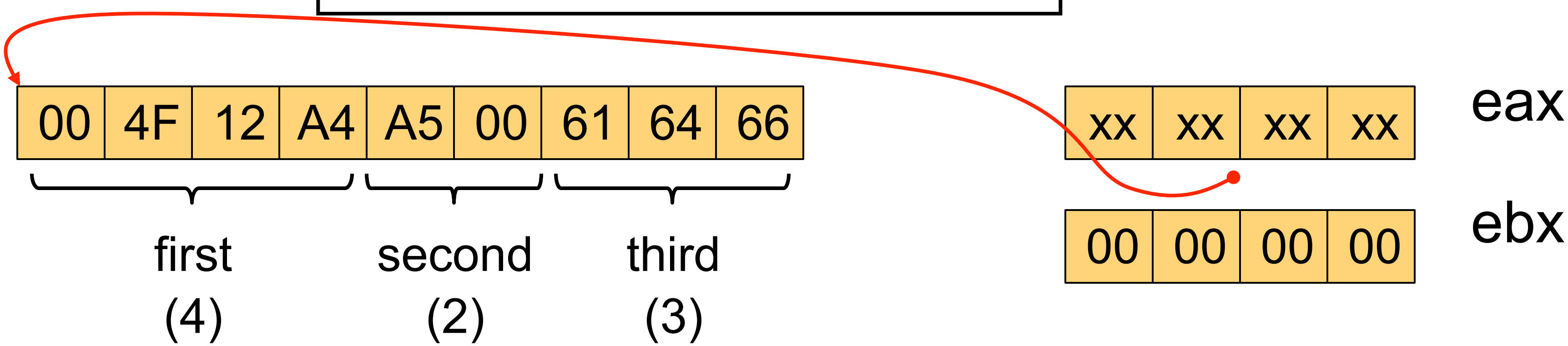


Example

```
first       db    00h, 04Fh, 012h, 0A4h
second      dw    165
third       db    "adf"
```

```
mov   eax, first
inc   eax
mov   ebx, [eax]
mov   [second], ebx
mov   byte [third], 11o
```

Put an **address** into eax (this works because our addresses are 32-bit and thus fit into 4-byte registers, just like any other 4-byte values!)

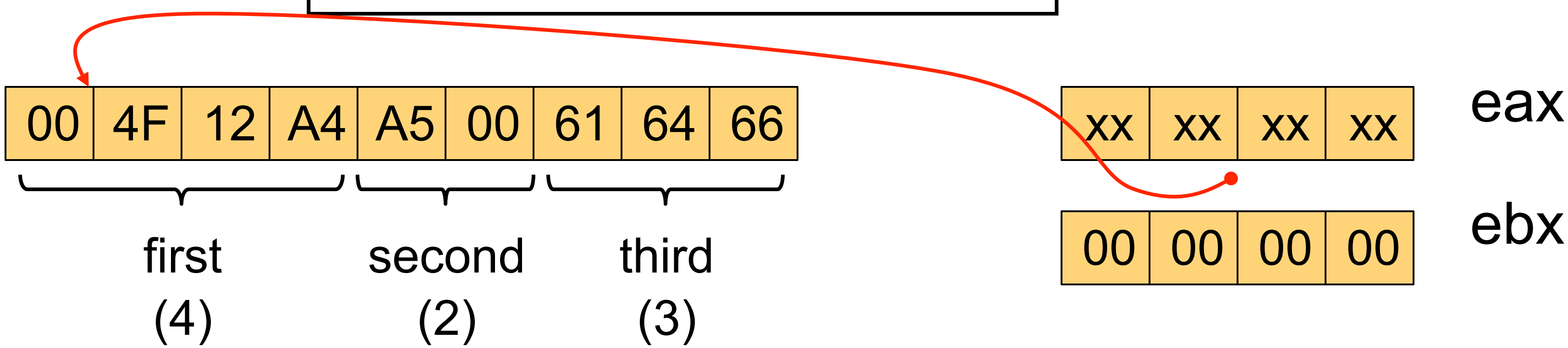


Example

```
first       db    00h, 04Fh, 012h, 0A4h
second      dw    165
third       db    "adf"
```

```
mov    eax, first
inc    eax
mov    ebx, [eax]
mov    [second], ebx
mov    byte [third], 11o
```

Increment that address by 1, thus now pointing to the next byte

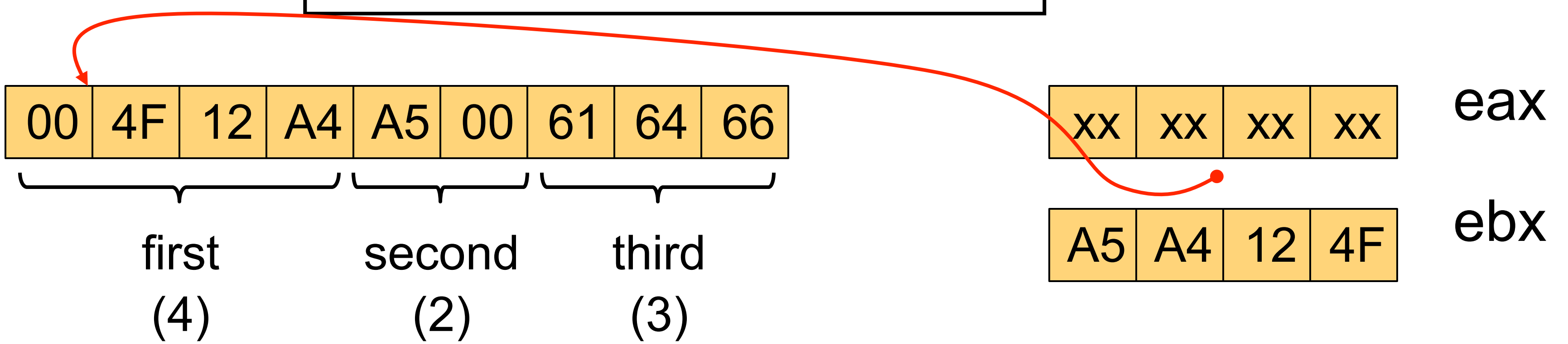


Example

```
first      db     00h, 04Fh, 012h, 0A4h
second     dw     165
third      db     "adf"
```

```
mov    eax, first
inc    eax
mov    ebx, [eax]
mov    [second], ebx
mov    byte [third], 11o
```

Put the 4 bytes at that address into ebx (note the Little Endian)

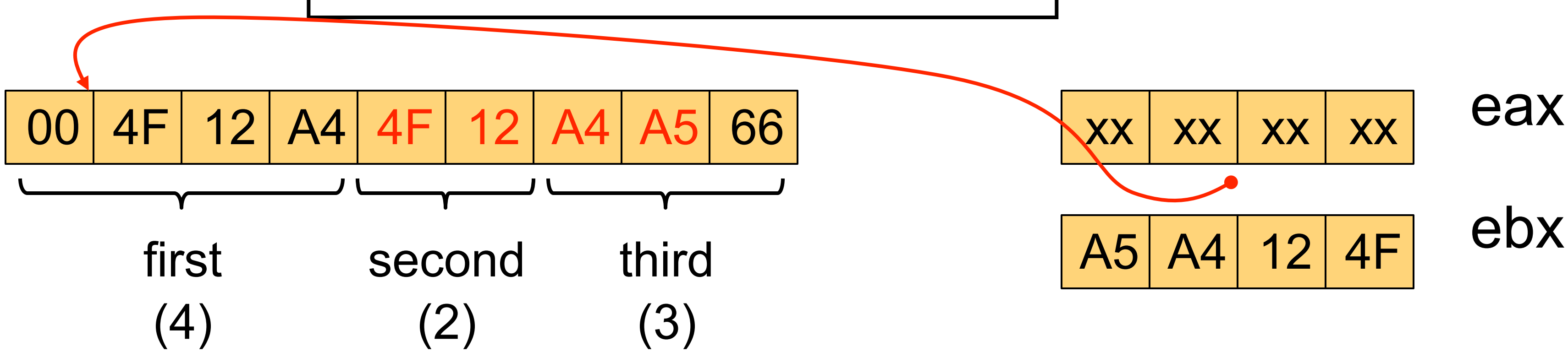


Example

```
first       db     00h, 04Fh, 012h, 0A4h
second      dw     165
third       db     "adf"
```

```
mov   eax, first
inc   eax
mov   ebx, [eax]
mov   [second], ebx
mov   byte [third], 11o
```

Copy 4 bytes to memory at address **second**

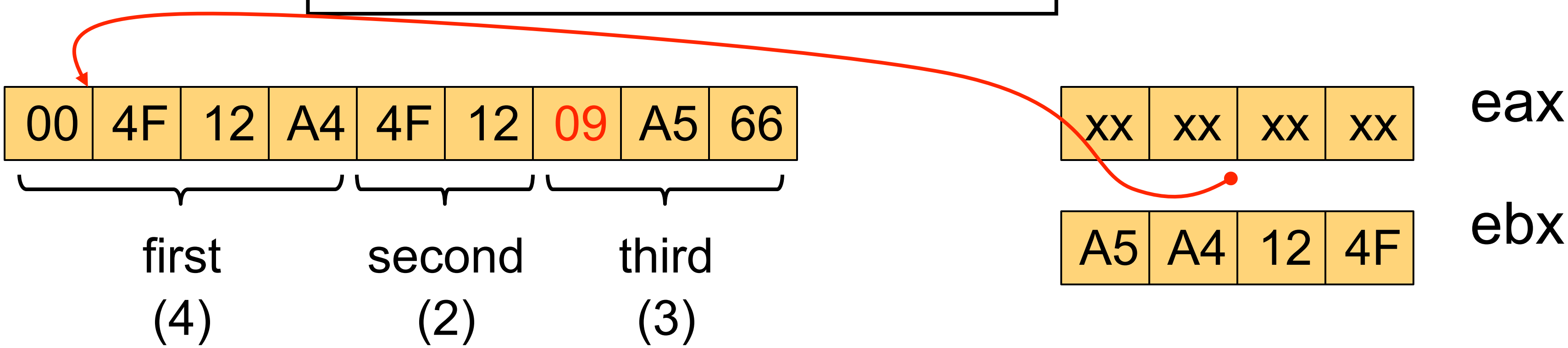


Example

```
first       db      00h, 04Fh, 012h, 0A4h
second      dw      165
third       db      "adf"
```

```
mov     eax, first
inc     eax
mov     ebx, [eax]
mov     [second], ebx
mov     byte [third], 11o
```

Write 1 byte at address **third**

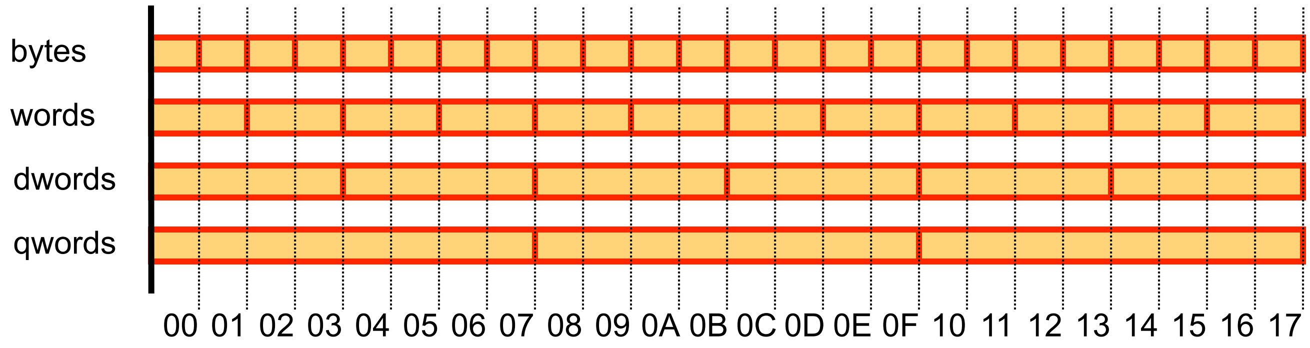


Assembly is Dangerous

- The previous example is really a terrible program
- But it’s a good demonstration of why the assembly programmer must be really careful
- For instance, we were able to store 4 bytes into a 2-byte label, thus overwriting the first 2 characters of a string that merely happened to be stored in memory next to that 2-byte label
  - again: LABELS ARE NOT VARIABLES AT ALL
- Playing such tricks can lead to very clever programs that do things that would be impossible (or very cumbersome) to do with many high-level programming language (e.g., in Java)
- But you really must know what you’re doing

x86 Assembly is Dangerous

- Another dangerous thing we did in our assembly program was the use of unaligned memory accesses
  - We stored a 4-byte quantity at some address
  - We incremented the address by 1
  - We read a 4-byte quantity from the incremented address!
  - This really removes all notion of a structured memory (it's only bytes)
- Some architectures only allow aligned accesses
  - Accessing an X-byte quantity can only be done for an address that's a multiple of X!



Practice #3

- Consider the following program

```
var1          dd      179
var2          db      0A3h, 017h, 012h
var3          db      "bca"
```

```
mov    eax, var1
add    eax, 3
mov    ebx, [eax]
add    ebx, 5
mov    [var1], ebx
```

- What is the final layout of the data segment starting at address var1 on a **Little Endian** Machine?

Practice #3

```
var1        dd      179
var2        db      0A3h, 017h, 012h
var3        db      "bca"
```

```
mov     eax, var1
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add     ebx, 5
mov     [var1], ebx
```

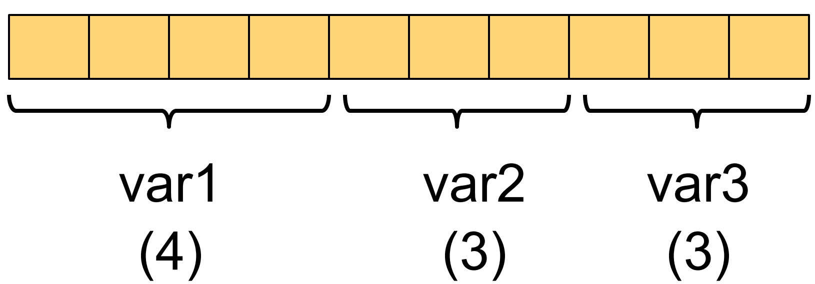

Practice #3

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var1        dd      179
var2        db      0A3h, 017h, 012h
var3        db      “bca”
```

```
mov     eax, var1
add     eax, 3
mov     ebx, [eax]
add     ebx, 5
mov     [var1], ebx
```

B3	00	00	00	A3	17	12	62	63	61

$\underbrace{B3\ 00\ 00\ 00}_{\text{var1 (4)}}\ \underbrace{A3\ 17\ 12}_{\text{var2 (3)}}\ \underbrace{62\ 63\ 61}_{\text{var3 (3)}}$

Practice #3

```
var1        dd      179
var2        db      0A3h, 017h, 012h
var3        db      "bca"
```

```
mov     eax, var1
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mov     [var1], ebx
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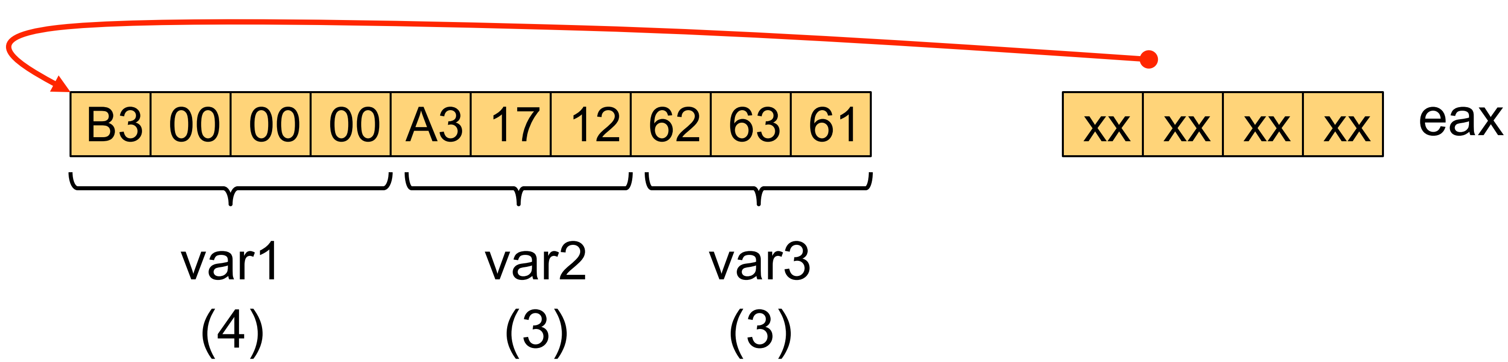

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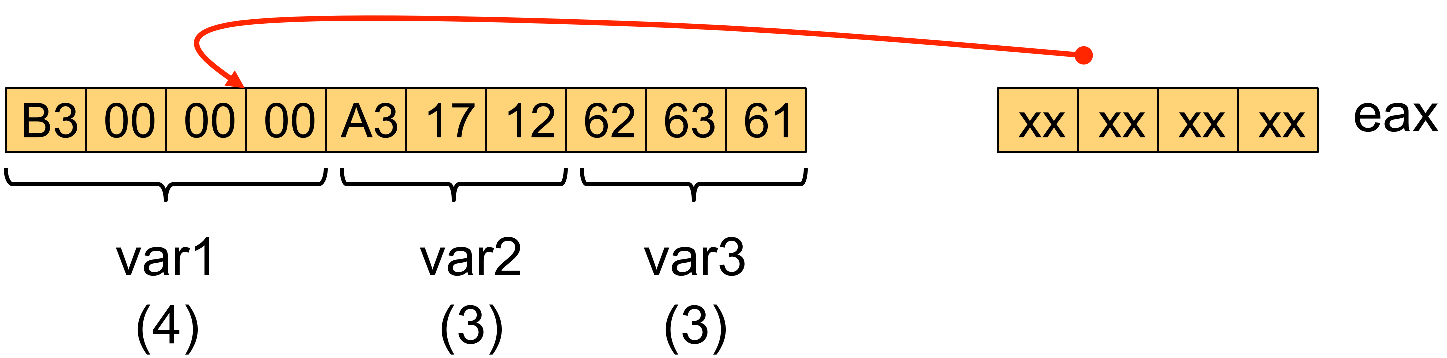

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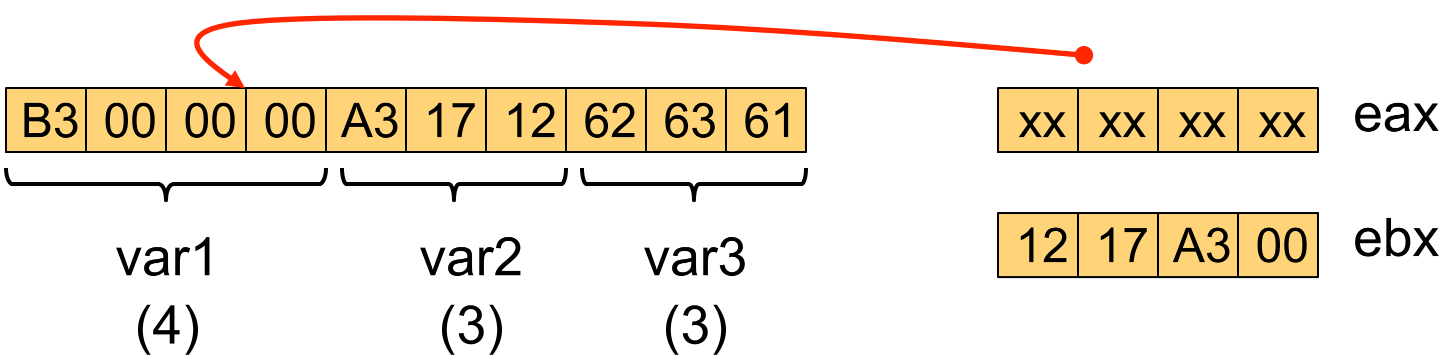

Practice #3

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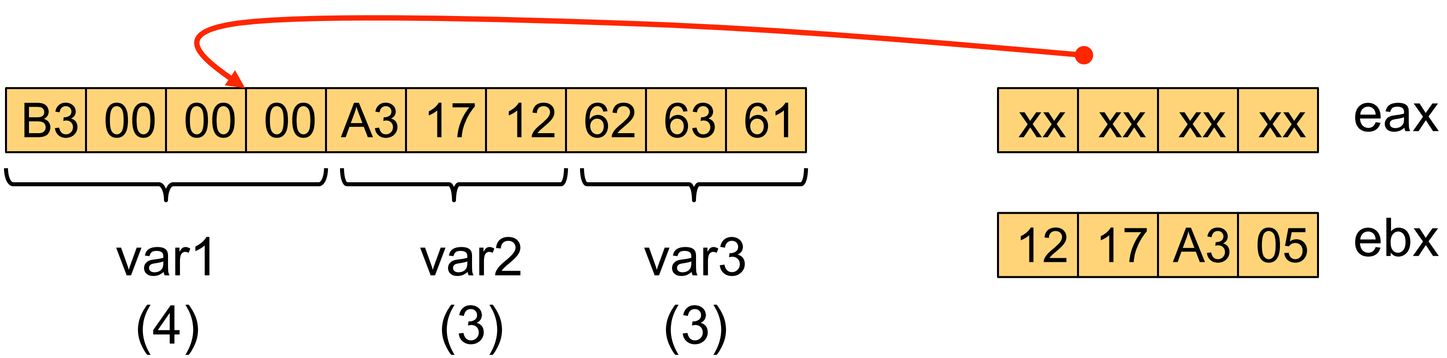

Practice #3

```
var1        dd      179
var2        db      0A3h, 017h, 012h
var3        db      “bca”
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mov     eax, var1
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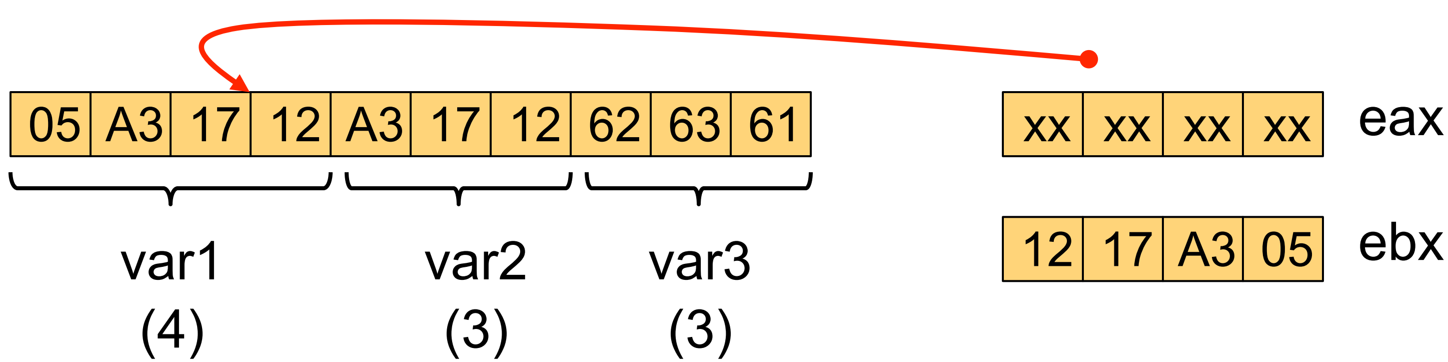


Practice #4

- Consider the following program

```
var1          db     "b","ca",0
var2          db   3,0,0,0
var3          times 2 dw    012h
```

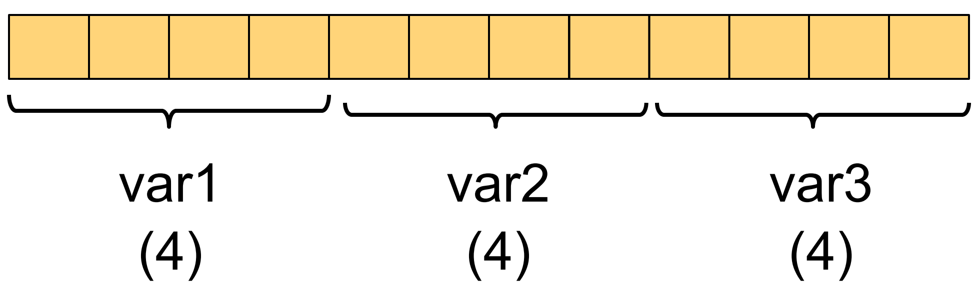
```
mov    eax, var3
mov    ebx, var1
sub    eax, 4
add    ebx, [eax]
mov    dword [ebx], 42
```

- What is the final layout of memory starting at address var1 on a Little Endian Machine?

Practice #4

```
var1        db      “b”,”ca”,0
var2        times   db 3,0,0,0
var3        times 2 dw    012h
```

```
mov    eax, var3
mov    ebx, var1
sub    eax, 4
add    ebx, [eax]
mov    dword [ebx], 42
```



Practice #4

```
var1          db       “b”,”ca”,0
var2          times   db 3,0,0,0
var3          times 2 dw    012h
```

```
mov    eax, var3
mov    ebx, var1
sub    eax, 4
add    ebx, [eax]
mov    dword [ebx], 42
```

62	63	61	00	03	00	00	00	12	00	12	00

var1 (4) var2 (4) var3 (4)

Practice #4

```
var1        db       "b","ca",0
var2        times    db 3,0,0,0
var3        times 2 dw    012h
```

```
mov    eax, var3
mov    ebx, var1
sub    eax, 4
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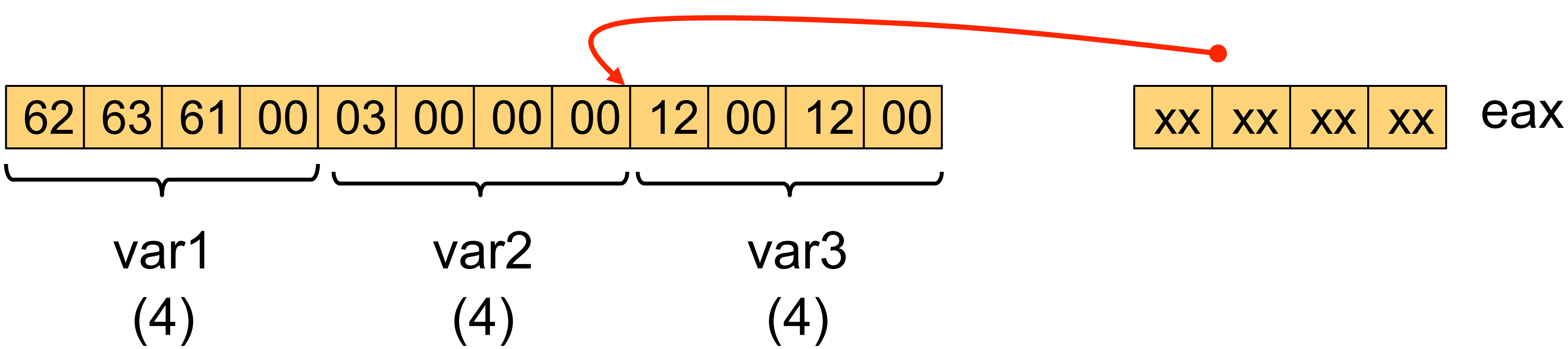

Practice #4

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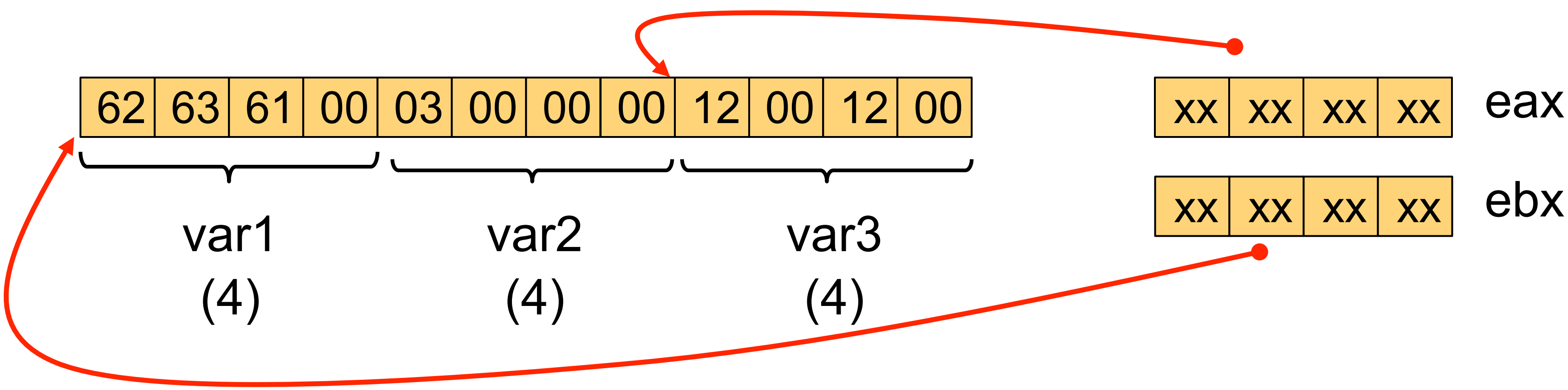

Practice #4

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var3        times 2 dw    012h
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mov    eax, var3
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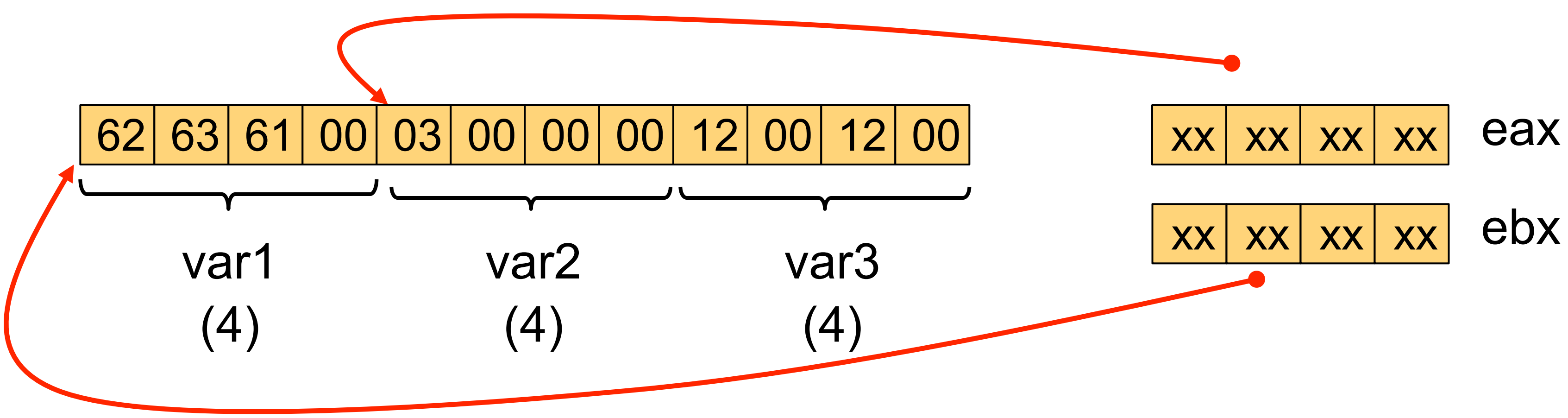

Practice #4

```
var1        db      "b","ca",0
var2        times   db 3,0,0,0
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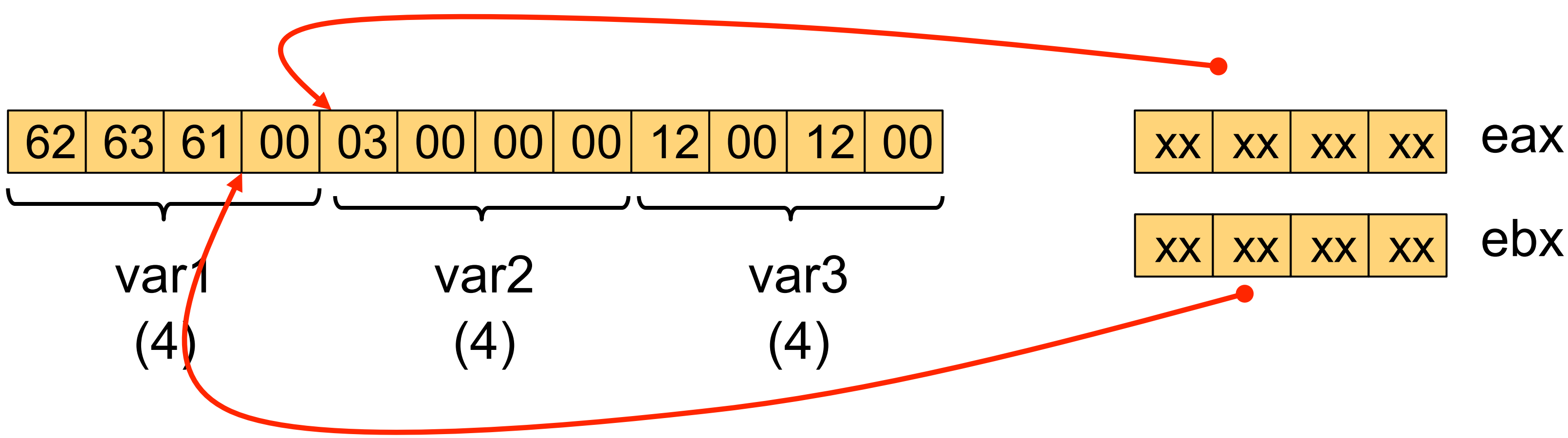

Practice #4

```
var1        db        "b","ca",0
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var3        times 2 dw     012h
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mov    eax, var3
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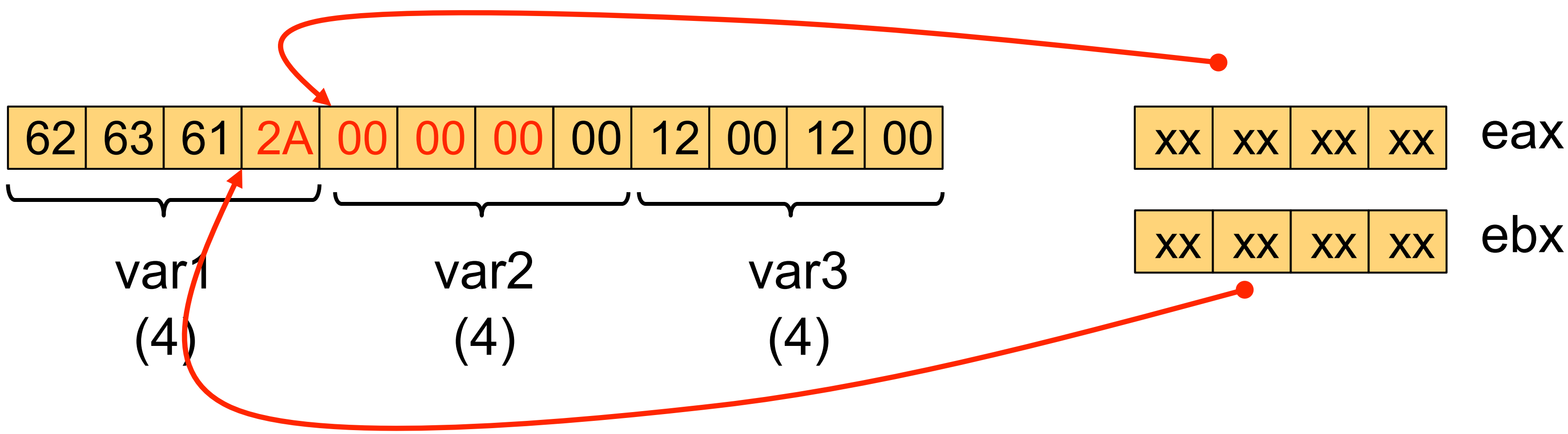

Conclusion

- Should we make up other practices now or are we good?
  - Somebody wants to propose one?

- We can now do Homework #2
- Next lecture we'll go through a practice quiz (Zoom poll) on this module…