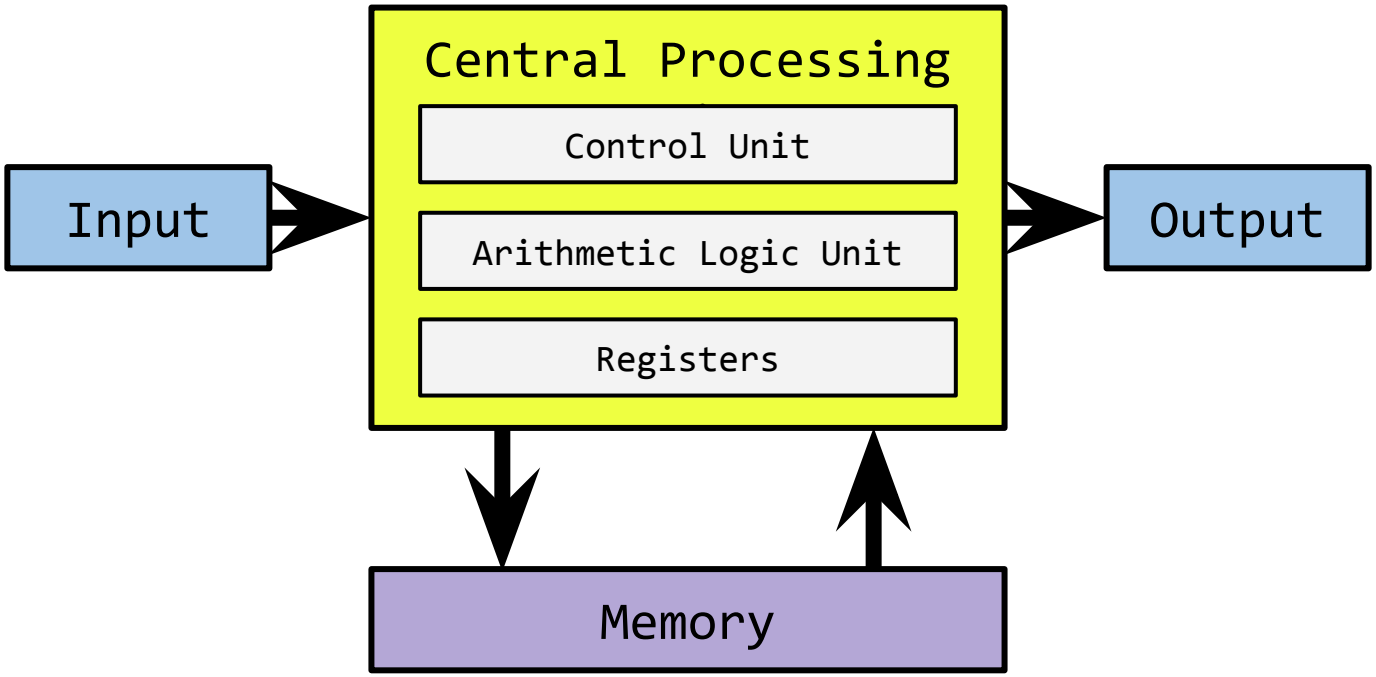
- ★ **A recap from the last week**
- ★ Scenario: Q&A
- ★ First and next steps in gdb

We have learnt about:

a simple computer architecture



We have learnt about:

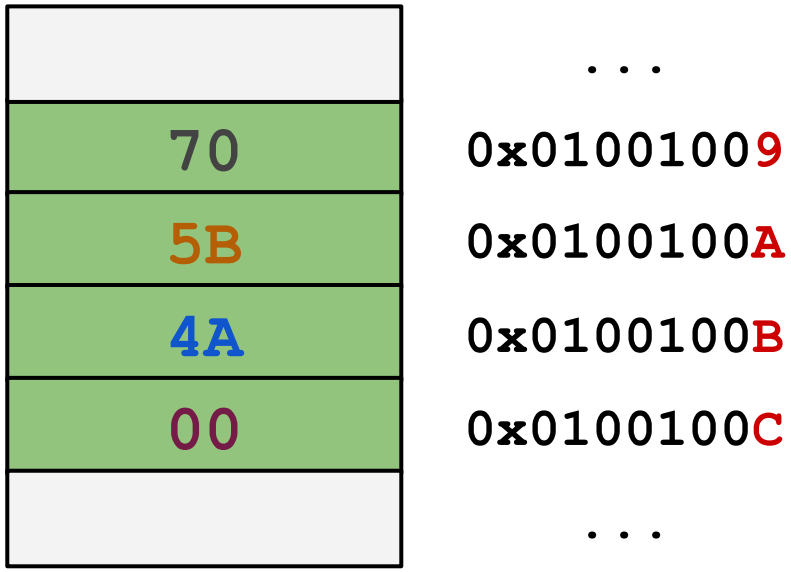
memory problem

We have learnt about:

We have learnt about:

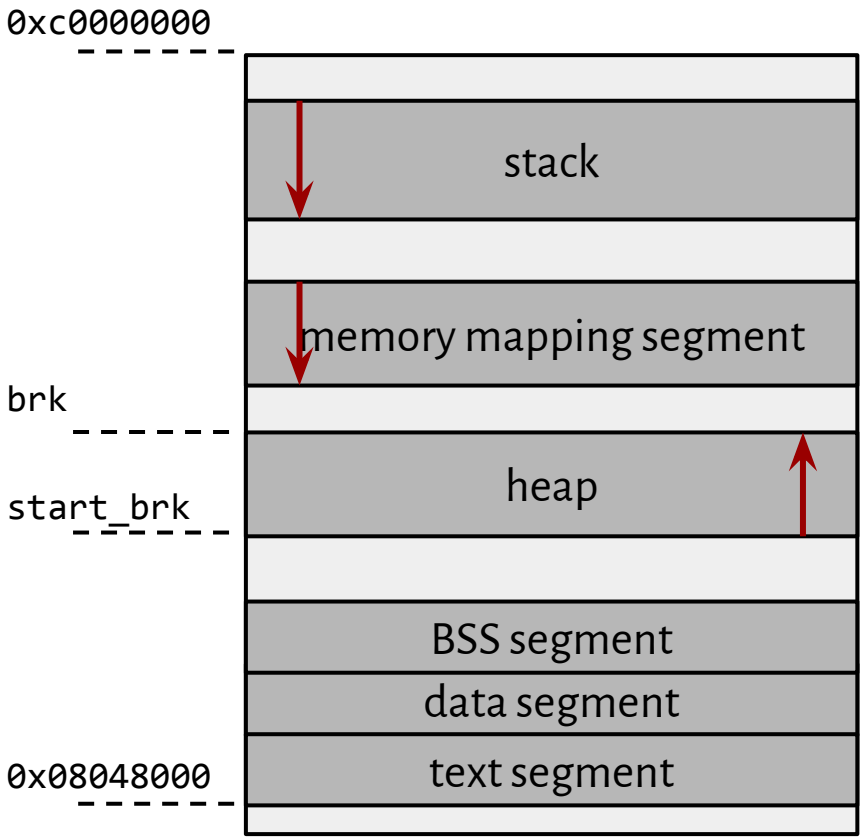
main memory

$(00\ 4A\ 5B\ 70)_{16}$



We have learnt about:

program memory layout



★ A recap from the last week

★ **Scenario: Q&A**

★ First and next steps in gdb

Scenario: A1

```
$ gcc -c -Wall -O2 a1.c -o a1.o
```

```
$ objdump -d -M intel_mnemonic a1.o
```

Scenario: A1

```
$ gcc -c -Wall -O2 a1.c -o a1.o
```

```
$ objdump -d -M intel_mnemonic a1.o
```

```
int64_t sddiv(int64_t x) {
  return x << 1;
}
```

```
uint64_t uddiv(uint64_t x) {
  return x << 1;
}
```

Scenario: A1

```
$ gcc -c -Wall -O2 a1.c -o a1.o
```

```
$ objdump -d -M intel_mnemonic a1.o
```

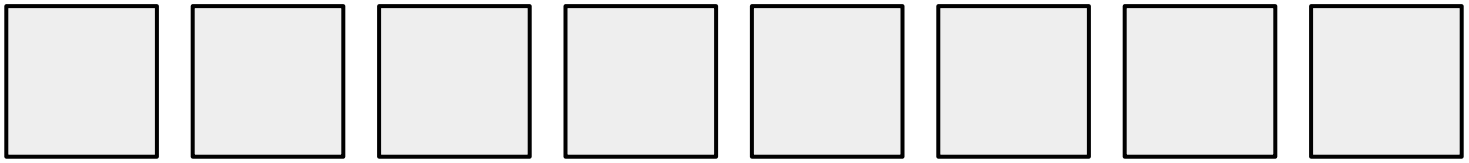
```
int64_t sddiv(int64_t x) {
  return x << 1;
}
```

```
mov rax,rdi
sar rax,1
```

```
uint64_t uddiv(uint64_t x) {
  return x << 1;
}
```

```
mov rax,rdi
shr rax,1
```

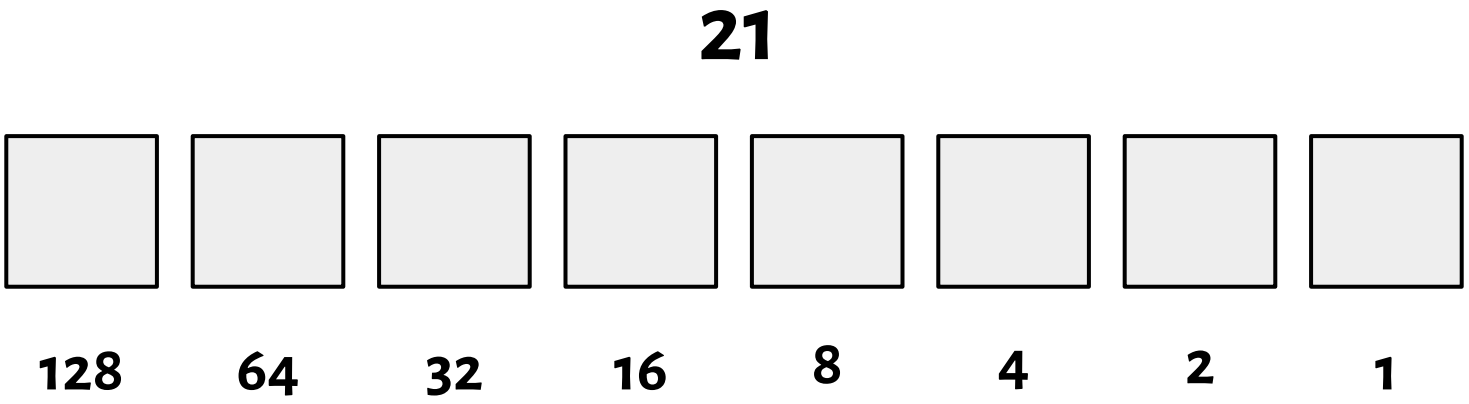
Unsigned integers in x86



$$x = \sum_{i \in [0,n)} 2^i \cdot t[i]$$

$n = 8$

Unsigned integers in x86



$$x = \sum_{i \in [0,n)} 2^i \cdot t[i]$$

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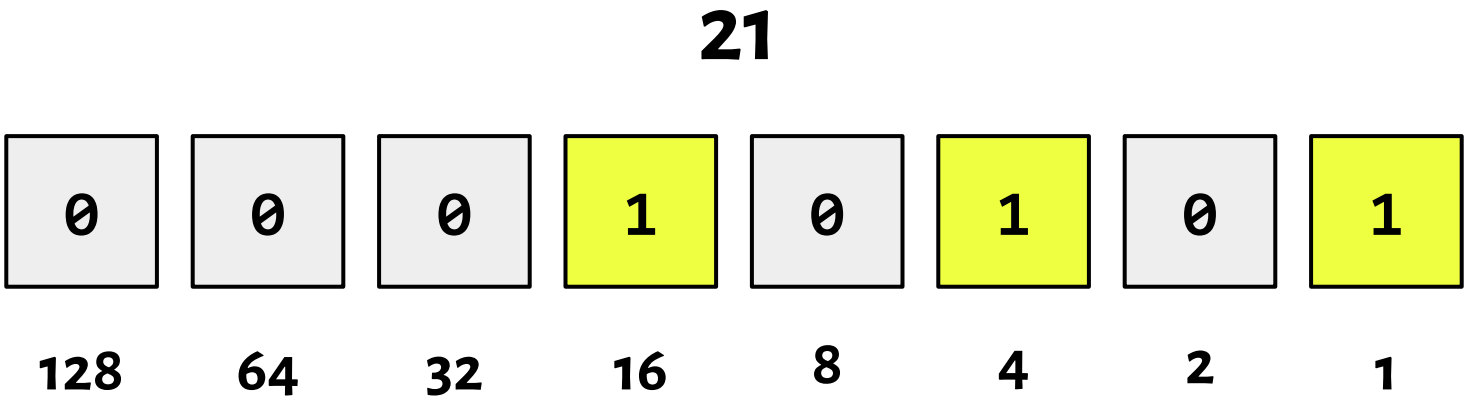
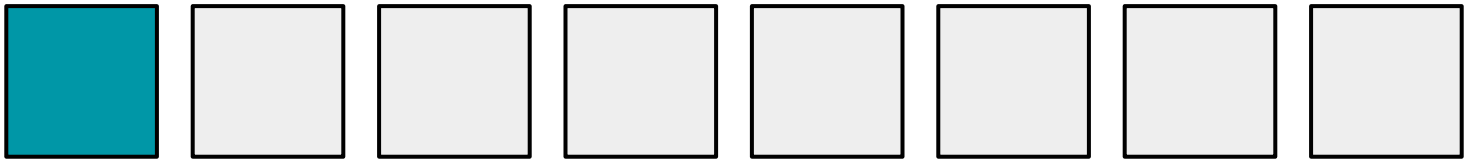
Unsigned integers in x86



$$x = \sum_{i \in [0,n)} 2^i \cdot t[i]$$

$n = 8$

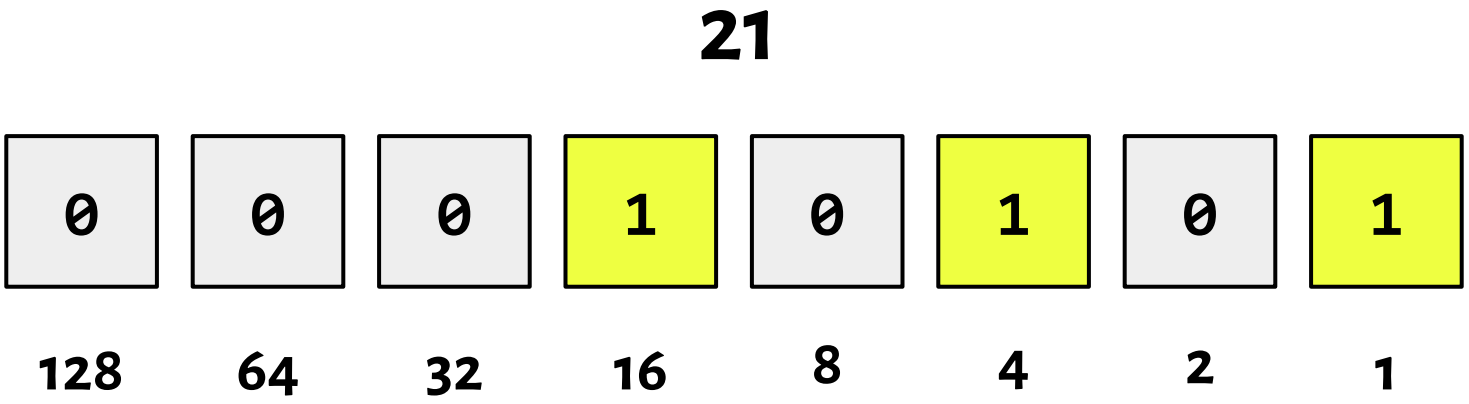
Signed integers in x86



$$x = (-1)^{t[n-1]} \cdot 2^{n-1} + \sum_{i \in [0,n-1)} 2^i \cdot t[i]$$

$n = 8$

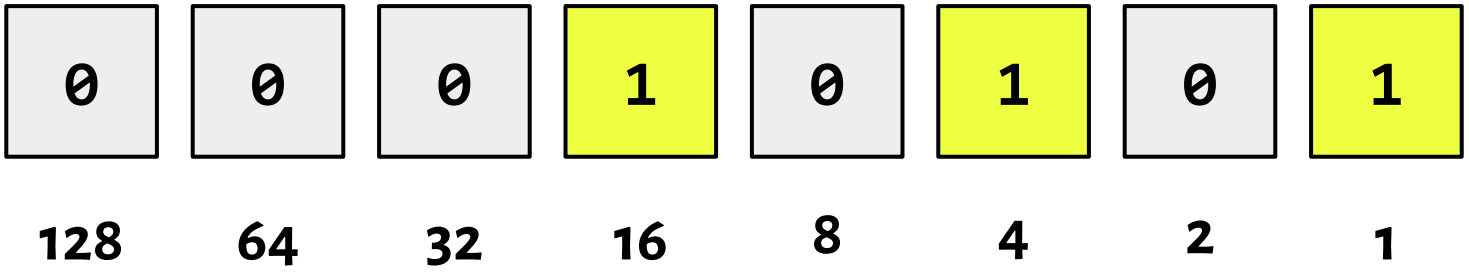
Signed integers in x86



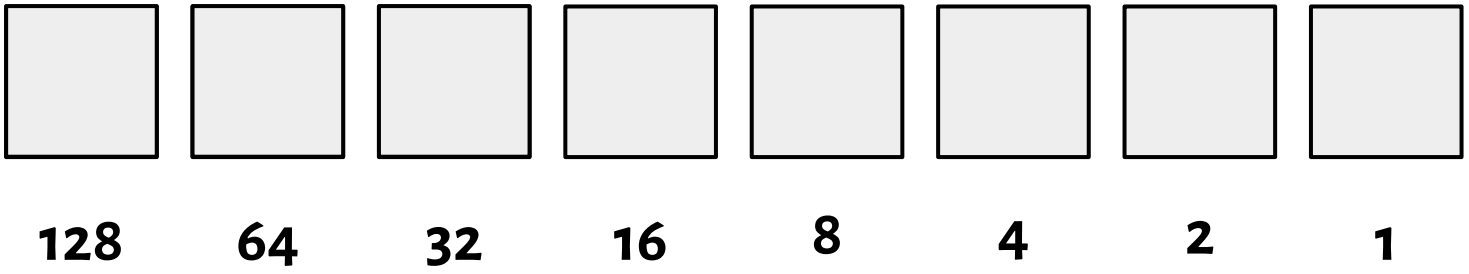
$n = 8$

Signed integers in x86

21



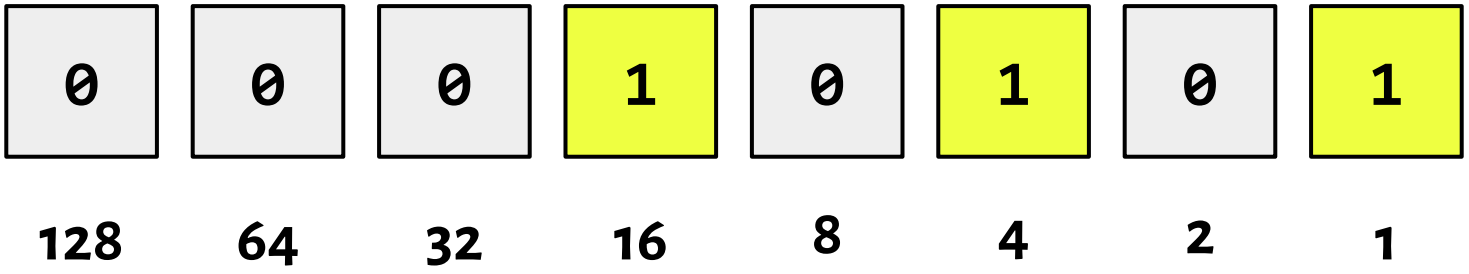
-21



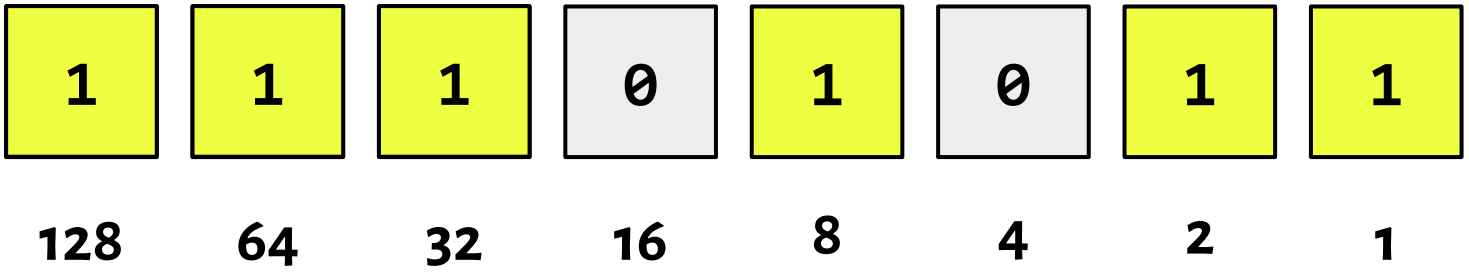
$n = 8$

Signed integers in x86

21

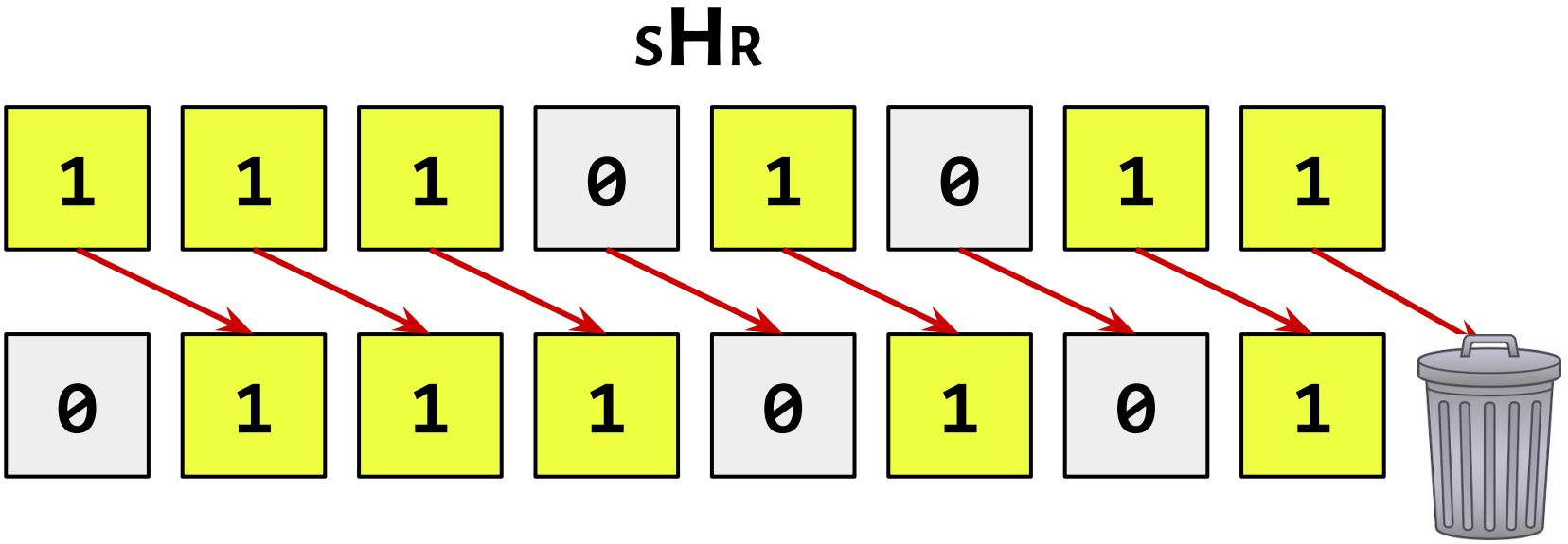


-21

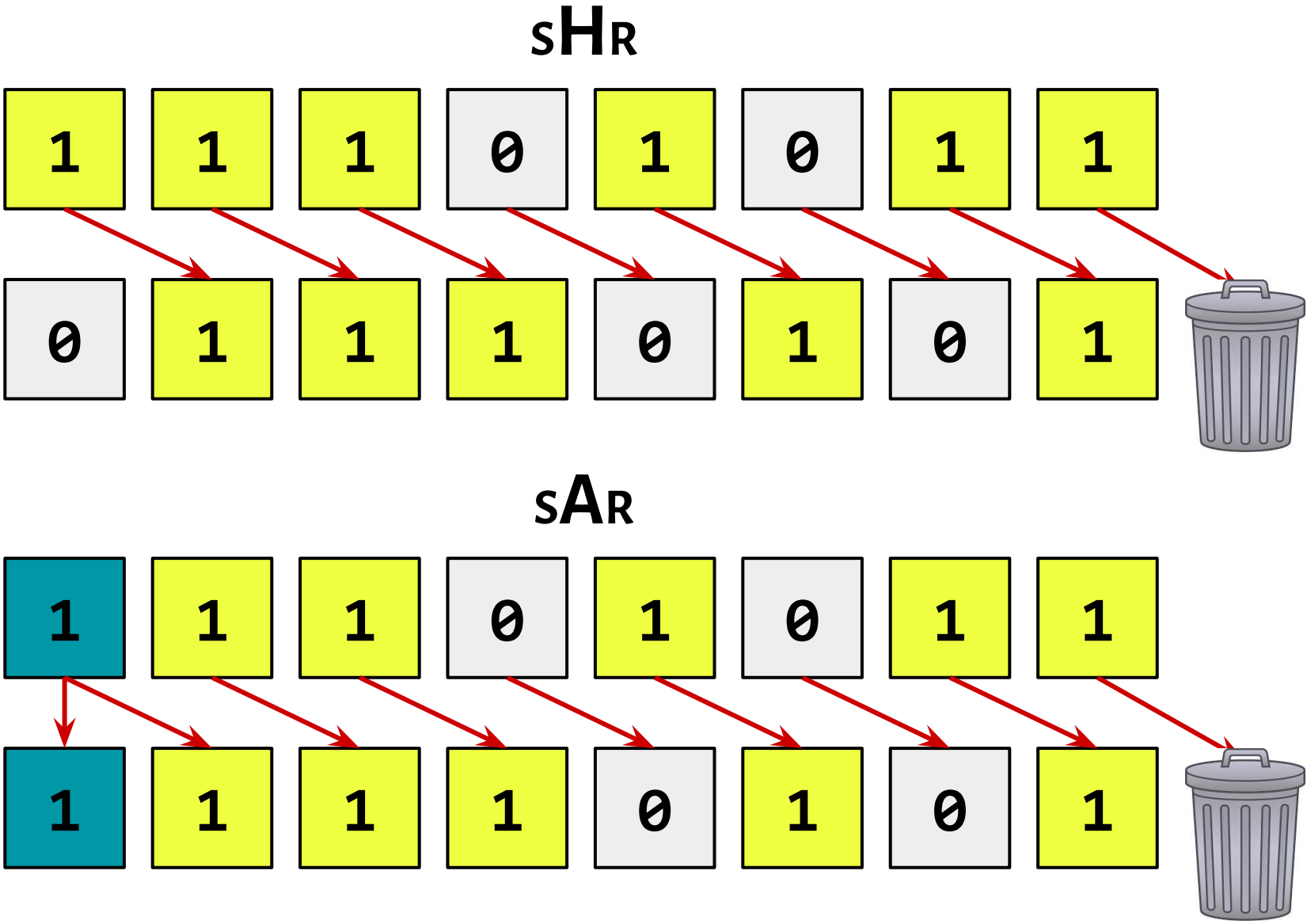


$n = 8$

SHR vs. SAR



SHR vs. SAR



Scenario: A1

```
$ gcc -c -Wall -O2 a1.c -o a1.o
```

```
$ objdump -d -M intel_mnemonic a1.o
```

```
int64_t sddiv(int64_t x) {
  return x / 2;
}
```

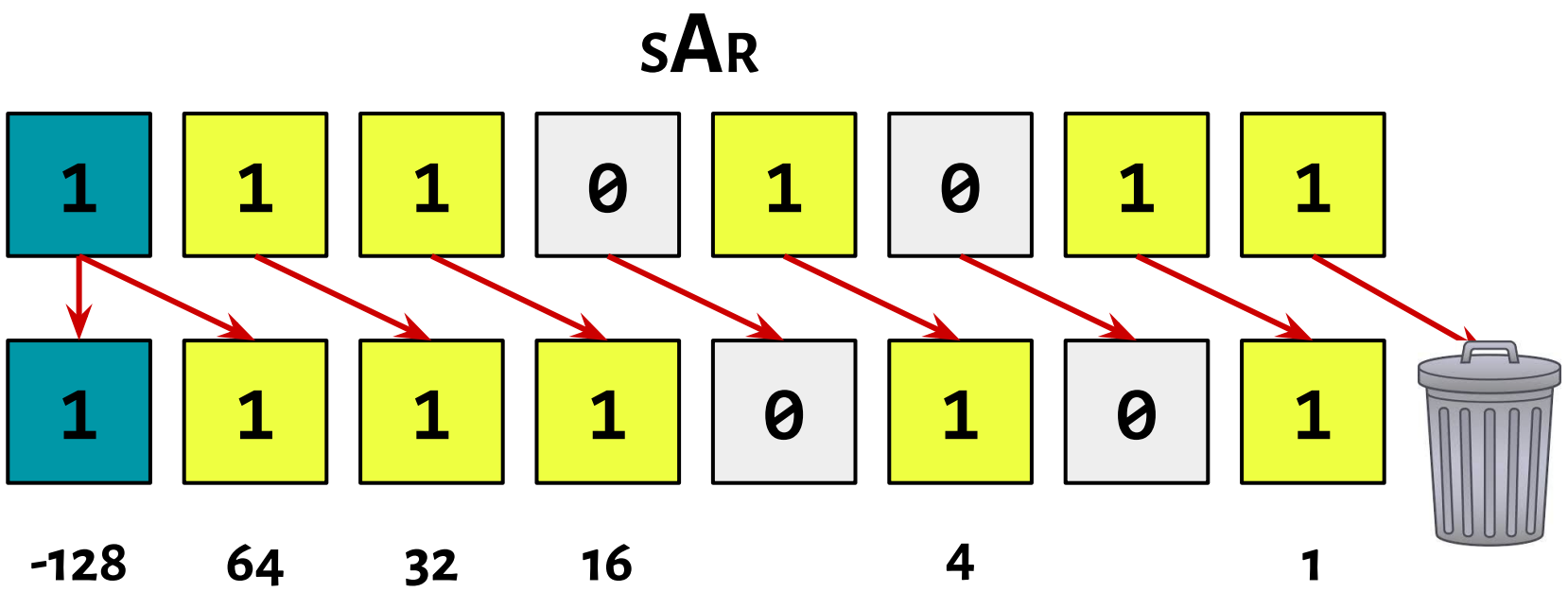
```
mov rax,rdi
shr rax,0x3f
add rax,rdi
sar rax,1
```

```
uint64_t uddiv(uint64_t x) {
  return x / 2;
}
```

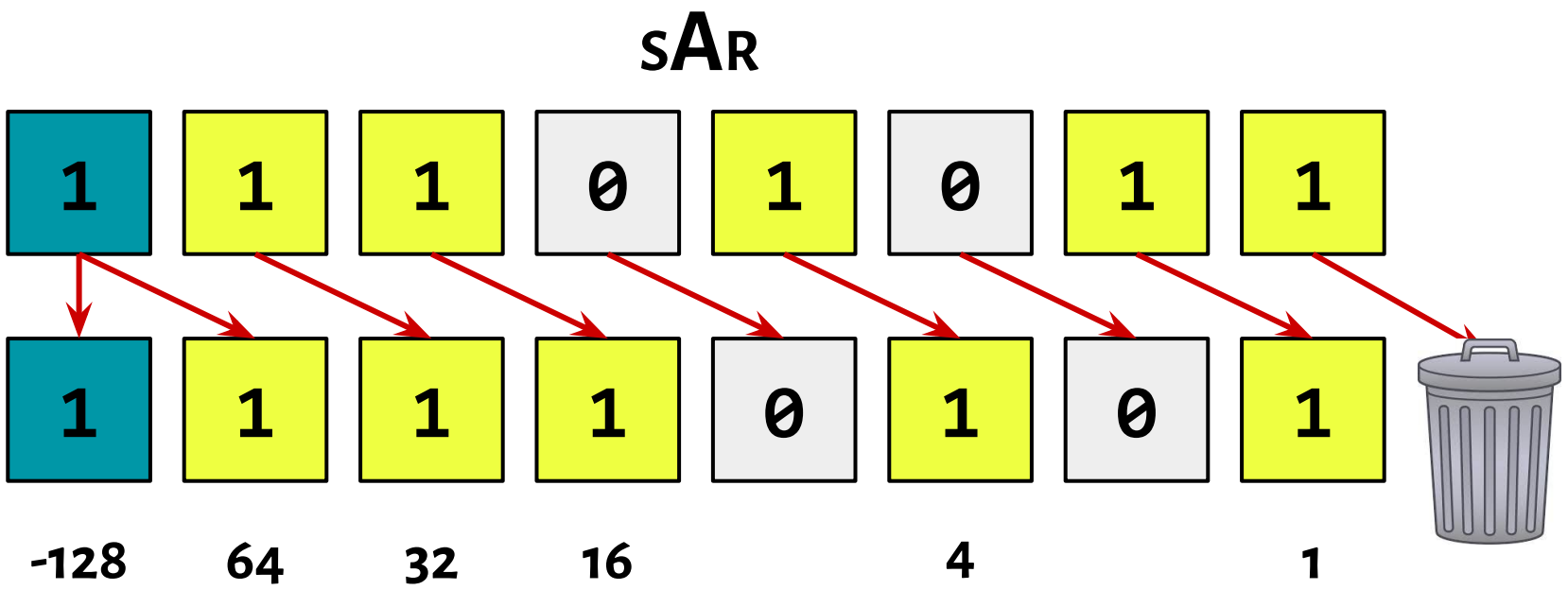
```
mov rax,rdi
shr rax,1
```

http://ithare.com/infographics-operation-costs-in-cpu-clock-cycles/

SHR vs. SAR



SHR vs. SAR



$X = -11$

Scenario: A1

```
$ gcc -c -Wall -O2 a1.c -o a1.o
```

```
$ objdump -d -M intel_mnemonic a1.o
```

```
int64_t smmul(int64_t x) {
  return x * 2;
}
```

```
lea rax,[rdi+rdi*1]
ret
```

```
uint64_t ummul(uint64_t x) {
  return x * 2;
}
```

```
lea rax,[rdi+rdi*1]
ret
```

Scenario: A1

```
$ gcc -c -Wall -O2 a1.c -o a1.o
```

```
$ objdump -d -M intel_mnemonic a1.o
```

```
int64_t smmul(int64_t x) {
  return x << 1;
}
```

```
lea rax,[rdi+rdi*1]
ret
```

```
uint64_t ummul(uint64_t x) {
  return x << 1;
}
```

```
lea rax,[rdi+rdi*1]
ret
```

LEA

Load Effective Address

LEA R3, [R1+a•R2+b]

a = 1, 2, 4 or 8

Sometimes faster and makes the code size smaller.

https://www.youtube.com/watch?v=7WrSaM7pcWY

Scenario: A2

Poeksperymentuj z innymi typami argumentów: wskaźniki, struktury, wskaźniki do struktur.

```
typedef struct {
    int a;
    int b;
    int c;
    char d;
    char e;
    char f;
} s_t;
```

```
int foo_a(s_t arg) {
    return arg.a;
}
```

Scenario: A2

Poeksperymentuj z innymi typami argumentów: wskaźniki, struktury, wskaźniki do struktur.

```
typedef struct {
    int a;
    int b;
    int c;
    char d;
    char e;
    char f;
} s_t;
```

```
int foo_a(s_t arg) {
    return arg.a;
}
```

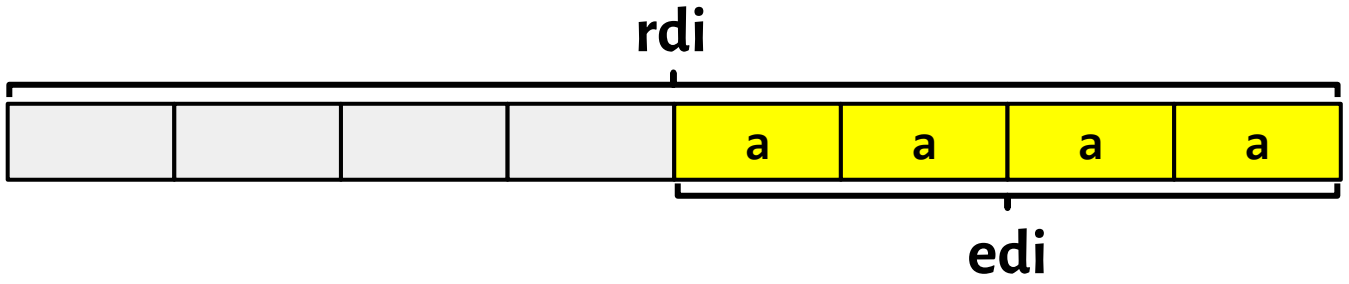
Scenario: A2

Poeksperymentuj z innymi typami argumentów: wskaźniki, struktury, wskaźniki do struktur.

```
typedef struct {
    int a;
    int b;
    int c;
    char d;
    char e;
    char f;
} s_t;
```

```
int foo_a(s_t arg) {
    return arg.a;
}
```

```
mov eax,edi
ret
```



Scenario: A2

Poeksperymentuj z innymi typami argumentów: wskaźniki, struktury, wskaźniki do struktur.

```
typedef struct {
    int a;
    int b;
    int c;
    char d;
    char e;
    char f;
} s_t;
```

```
int foo_b(s_t arg) {
    return arg.b;
}
```

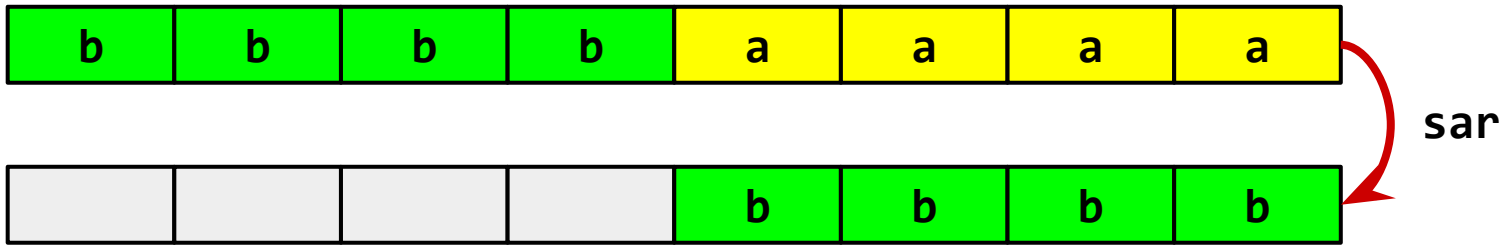
Scenario: A2

Poeksperymentuj z innymi typami argumentów: wskaźniki, struktury, wskaźniki do struktur.

```
typedef struct {
    int a;
    int b;
    int c;
    char d;
    char e;
    char f;
} s_t;
```

```
int foo_b(s_t arg) {
    return arg.b;
}
```

```
mov rax,rdi
sar rax,0x20
ret
```



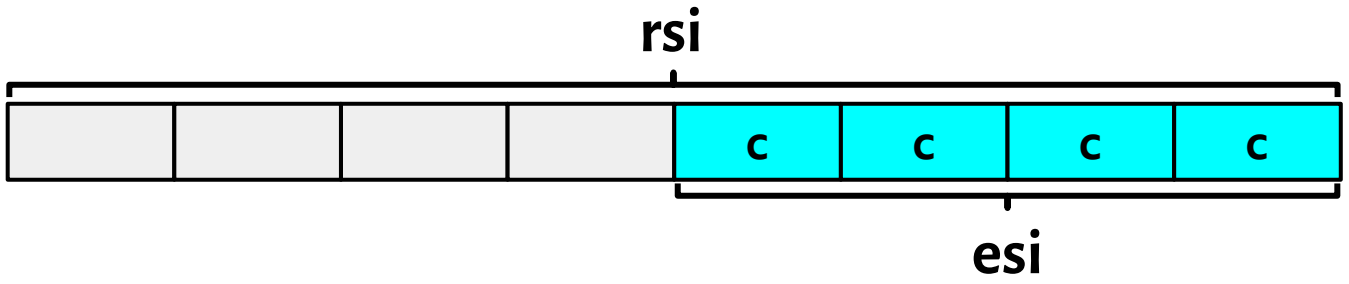
Scenario: A2

Poeksperymentuj z innymi typami argumentów: wskaźniki, struktury, wskaźniki do struktur.

```
typedef struct {
    int a;
    int b;
    int c;
    char d;
    char e;
    char f;
} s_t;
```

```
int foo_c(s_t arg) {
    return arg.c;
}
```

```
mov eax,esi
ret
```

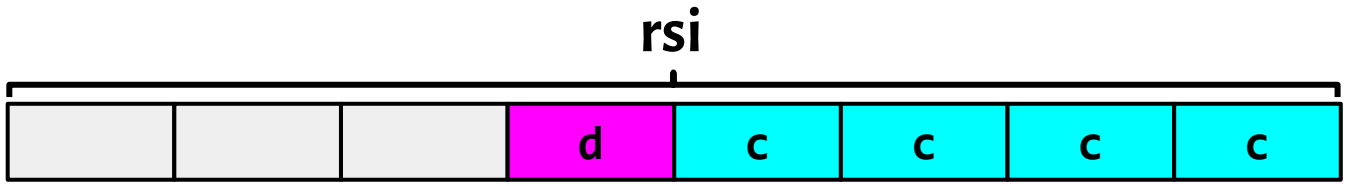


Scenario: A2

Poeksperymentuj z innymi typami argumentów: wskaźniki, struktury, wskaźniki do struktur.

```
typedef struct {
    int a;
    int b;
    int c;
    char d;
    char e;
    char f;
} s_t;
```

```
char foo_d(s_t arg) {
    return arg.d;
}
```



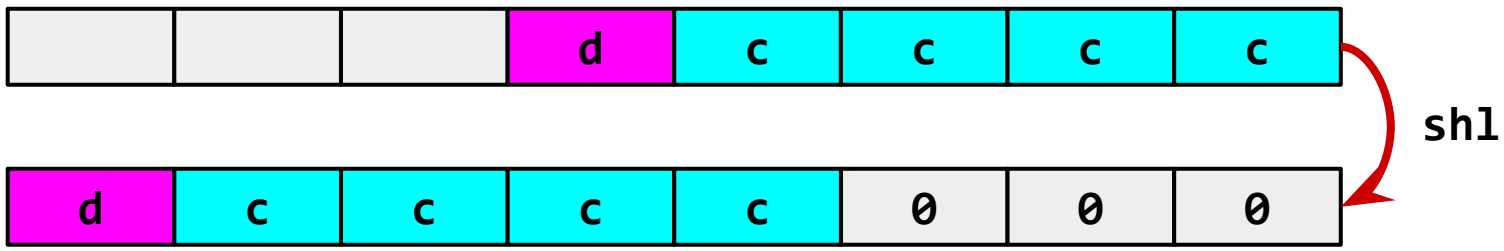
Scenario: A2

Poeksperymentuj z innymi typami argumentów: wskaźniki, struktury, wskaźniki do struktur.

```
typedef struct {
    int a;
    int b;
    int c;
    char d;
    char e;
    char f;
} s_t;
```

```
char foo_d(s_t arg) {
    return arg.d;
}
```

```
mov rax,rsi
shl rax,0x18
```



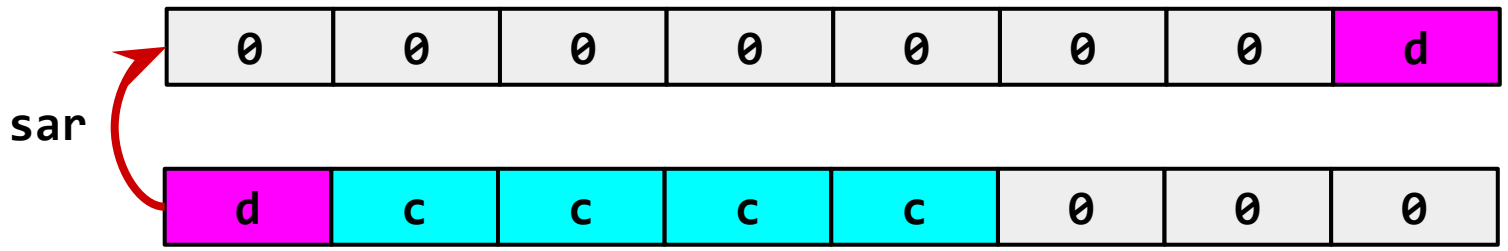
Scenario: A2

Poeksperymentuj z innymi typami argumentów: wskaźniki, struktury, wskaźniki do struktur.

```
typedef struct {
    int a;
    int b;
    int c;
    char d;
    char e;
    char f;
} s_t;
```

```
char foo_d(s_t arg) {
    return arg.d;
}
```

```
mov rax,rsi
shl rax,0x18
sar rax,0x38
ret
```



Scenario: A3

Poeksperymentuj ze zwracaniem wartości innych typów, wskaźników, struktur, wskaźników do struktur.

```
typedef struct {
    int a;
    int b;
    int c;
    char d;
    char e;
    char f;
} s_t;
```

Scenario: A3

Poeksperymentuj ze zwracaniem wartości innych typów, wskaźników, struktur, wskaźników do struktur.

```
typedef struct {
    int a;
    int b;
    int c;
    char d;
    char e;
    char f;
} s_t;
```

```
s_t bar1() {
    s_t s;
    s.a = 1;
    s.b = 2;
    s.c = 3;
    s.d = 'a';
    s.e = 'b';
    s.f = 'c';
    return s;
}
```

Scenario: A3

Poeksperymentuj ze zwracaniem wartości innych typów, wskaźników, struktur, wskaźników do struktur.

```
typedef struct {
    int a;
    int b;
    int c;
    char d;
    char e;
    char f;
} s_t;
```

```
s_t bar1() {
    s_t s;
    s.a = 1;
    s.b = 2;
    s.c = 3;
    s.d = 'a';
    s.e = 'b';
    s.f = 'c';
    return s;
}
```

```
movabs rax,0x200000001
movabs rdx,0x6362610000003
ret
```

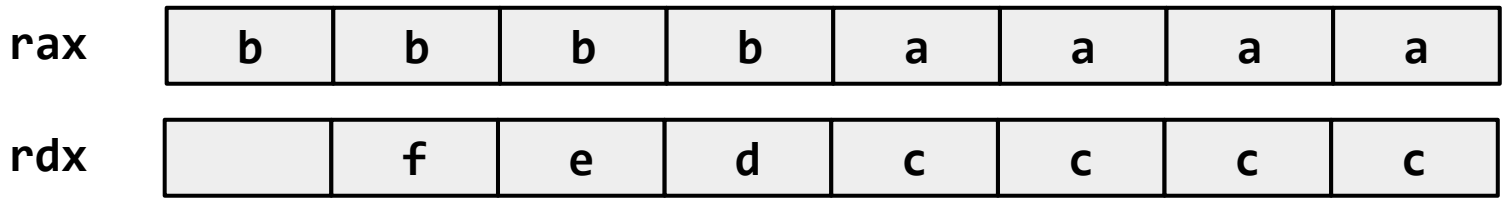
Scenario: A3

Poeksperymentuj ze zwracaniem wartości innych typów, wskaźników, struktur, wskaźników do struktur.

```
typedef struct {
    int a;
    int b;
    int c;
    char d;
    char e;
    char f;
} s_t;
```

```
s_t bar1() {
    s_t s;
    s.a = 1;
    s.b = 2;
    s.c = 3;
    s.d = 'a';
    s.e = 'b';
    s.f = 'c';
    return s;
}
```

```
movabs rax,0x200000001
movabs rdx,0x6362610000003
ret
```



Scenario: A3

Poeksperymentuj ze zwracaniem wartości innych typów, wskaźników, struktur, wskaźników do struktur.

```
typedef struct {
    int a;
    int b;
    int c;
    char d;
    char e;
    char f;
    int g;
} s_t;
```

```
s_t bar1() {
    s_t s;
    s.a = 1;
    s.b = 2;
    s.c = 3;
    s.d = 'a';
    s.e = 'b';
    s.f = 'c';
    s.g = 42;
    return s;
}
```

Scenario: A3

Poeksperymentuj ze zwracaniem wartości innych typów, wskaźników, struktur, wskaźników do struktur.

```
typedef struct {
    int a;
    int b;
    int c;
    char d;
    char e;
    char f;
    int g;
} s_t;
```

```
s_t bar1() {
    s_t s;
    s.a = 1;
    s.b = 2;
    s.c = 3;
    s.d = 'a';
    s.e = 'b';
    s.f = 'c';
    s.g = 42;
    return s;
}
```

```
mov rax,rdi
mov DWORD [rdi],0x1
mov DWORD [rdi+0x4],0x2
mov DWORD [rdi+0x8],0x3
mov BYTE [rdi+0xc],0x61
mov BYTE [rdi+0xd],0x62
mov BYTE [rdi+0xe],0x63
mov DWORD [rdi+0x10],0x2a
ret
```

Scenario: A4

Zaimplementuj w asemblerze funkcję o sygnaturze

```
uint128_t mac (uint128_t const *a,
               uint128_t const *x,
               uint128_t const *y);
```

która oblicza wartość a + x · y modulo 2 do potęgi 128.

Scenario: A4

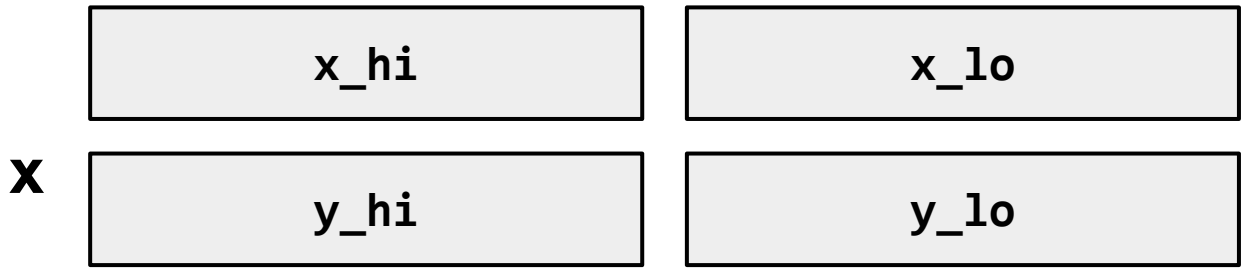
Zaimplementuj w asemblerze funkcję o sygnaturze

```
uint128_t mac (uint128_t const *a,
               uint128_t const *x,
               uint128_t const *y);
```

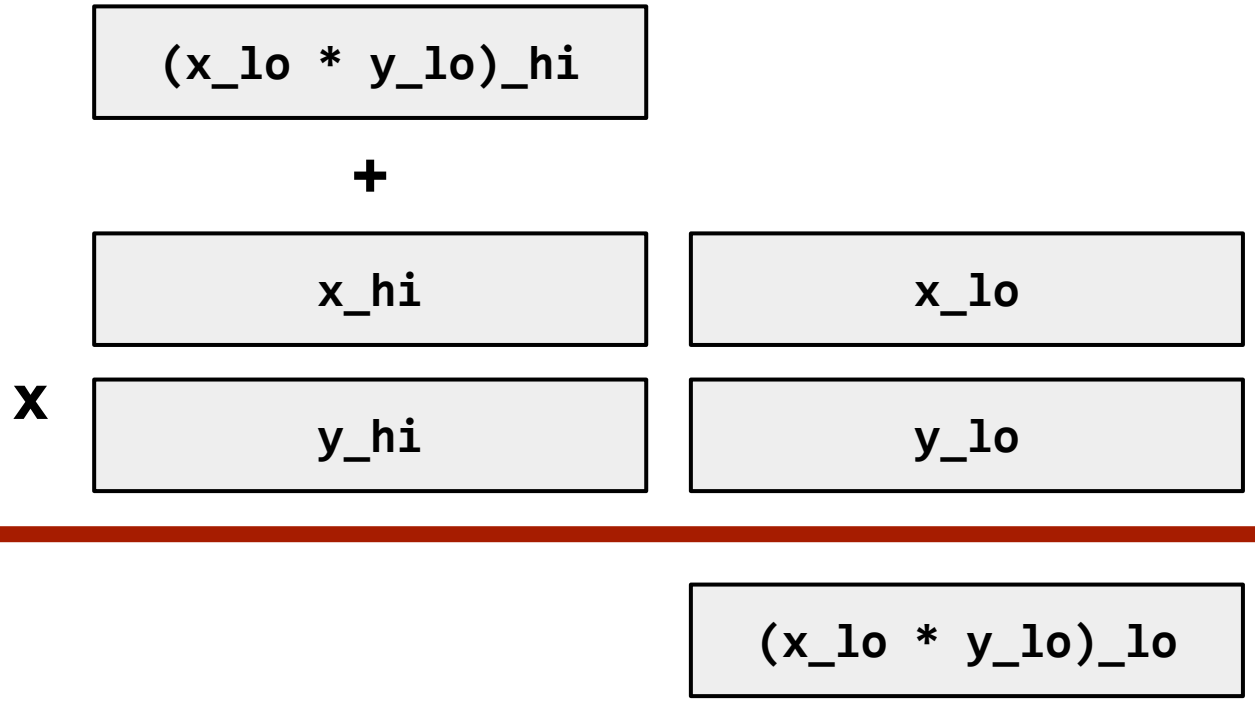
która oblicza wartość a + x · y modulo 2 do potęgi 128.

```
typedef struct {
   uint64_t lo;
   uint64_t hi;
} uint128_t
```

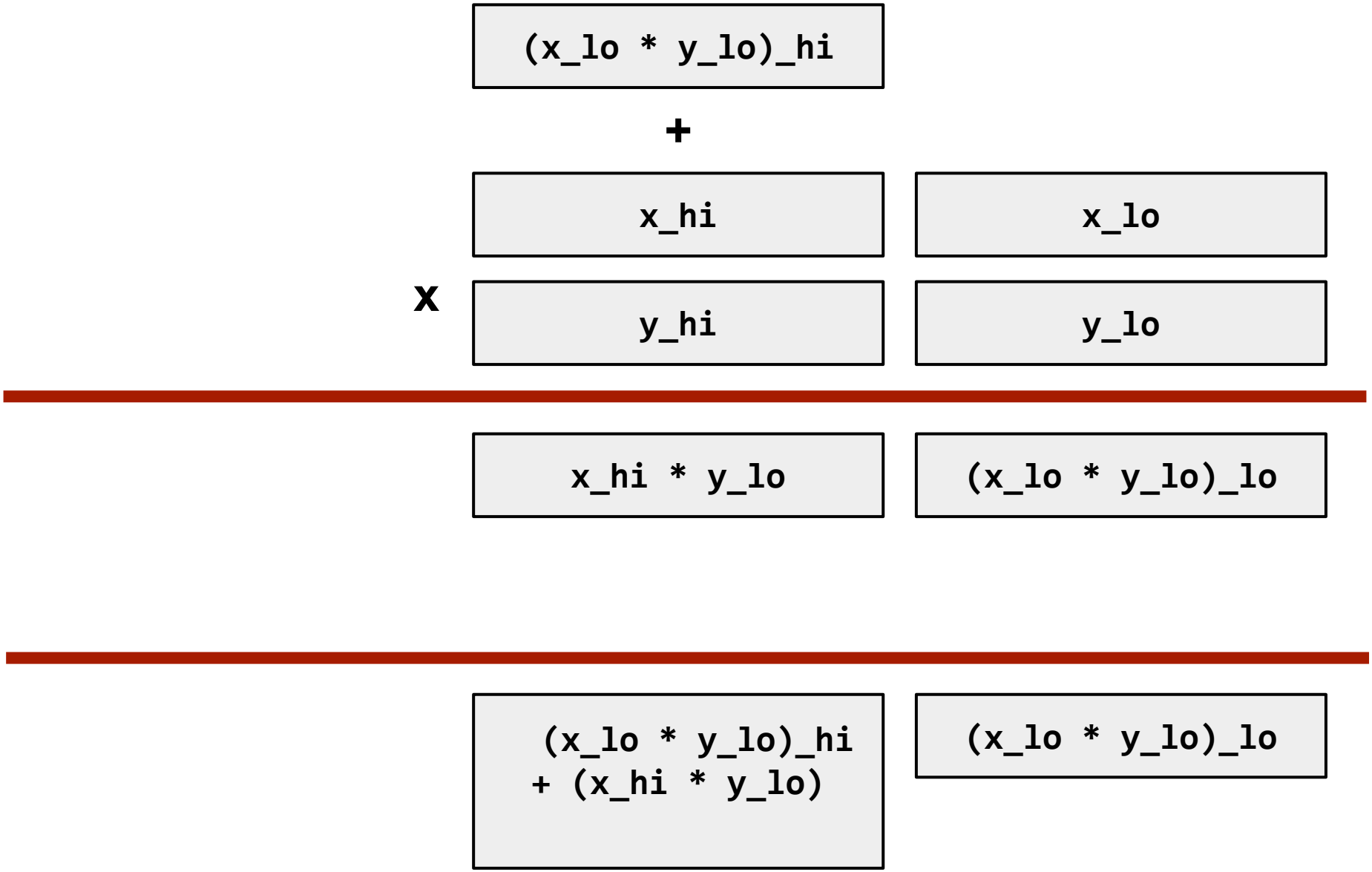
Scenario: A4



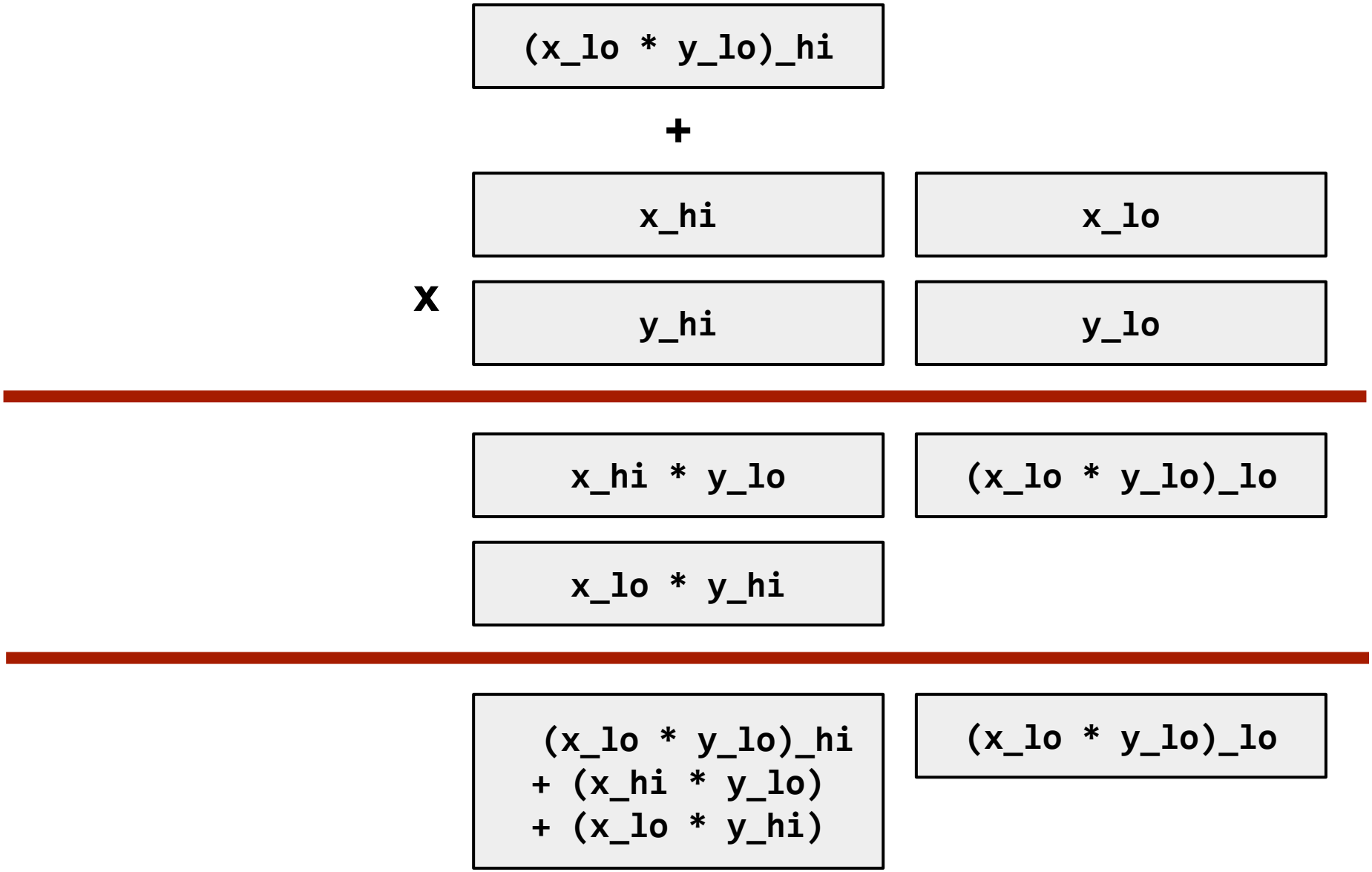
Scenario: A4



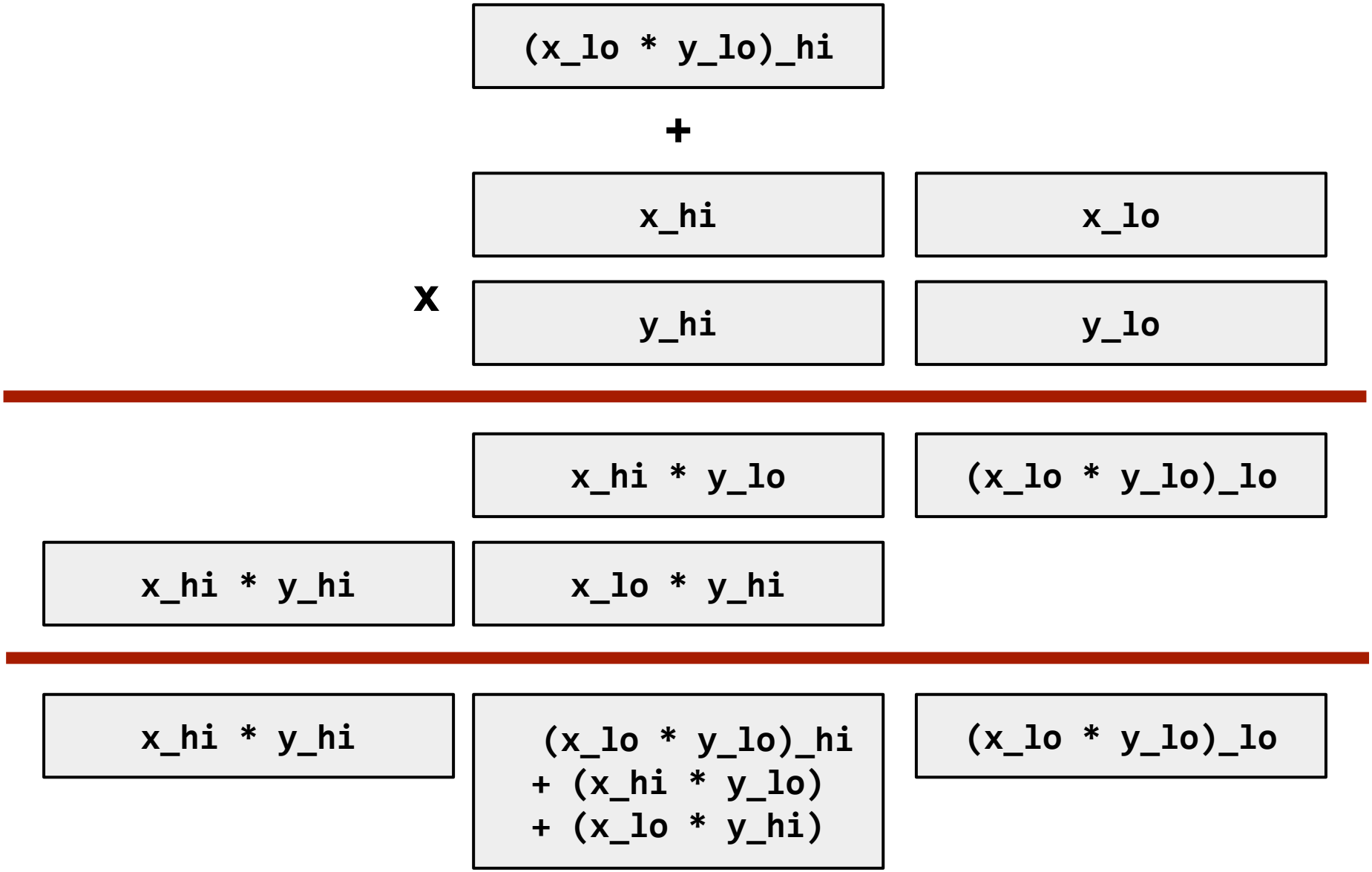
Scenario: A4


(x_lo * y_lo)_hi
+
x_hi
x_lo
x
y_hi
y_lo
x_hi * y_lo
(x_lo * y_lo)_lo
(x_lo * y_lo)_hi
+ (x_hi * y_lo)
(x_lo * y_lo)_lo

Scenario: A4


(x_lo * y_lo)_hi
+
x_hi
x_lo
x
y_hi
y_lo
x_hi * y_lo
(x_lo * y_lo)_lo
x_lo * y_hi
(x_lo * y_lo)_hi
+ (x_hi * y_lo)
+ (x_lo * y_hi)
(x_lo * y_lo)_lo

Scenario: A4

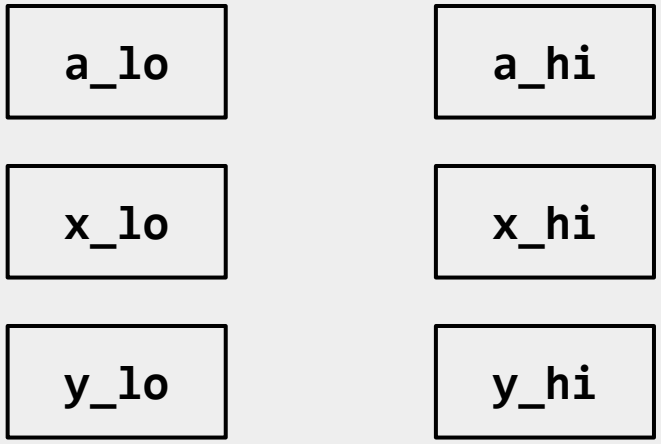

(x_lo * y_lo)_hi
+
x_hi
x_lo
x
y_hi
y_lo
x_hi * y_lo
(x_lo * y_lo)_lo
x_hi * y_hi
x_lo * y_hi
x_hi * y_hi
(x_lo * y_lo)_hi
+ (x_hi * y_lo)
+ (x_lo * y_hi)
(x_lo * y_lo)_lo

Scenario: A4

```
global mac

section .text

; rdi: a
; rsi: x
; rdx: y
```



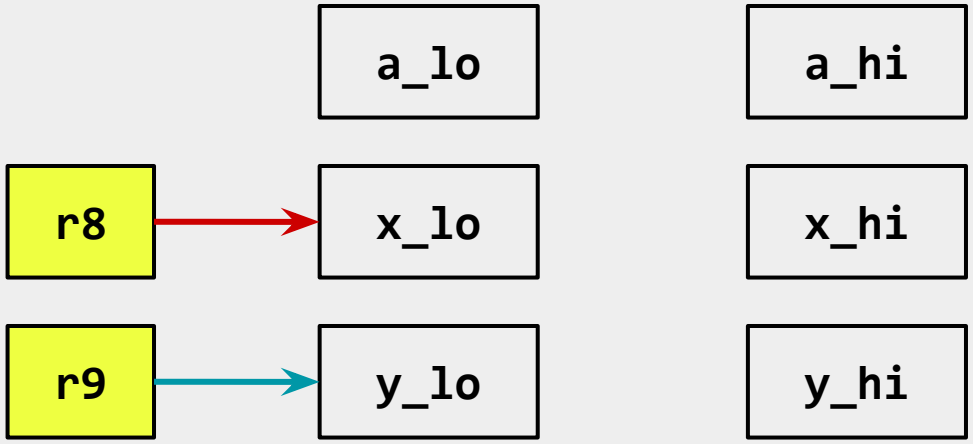
Scenario: A4

```
global mac

section .text

; rdi: a
; rsi: x
; rdx: y

mac:
    mov  r8, [rsi]
    mov  r9, [rdx]
```



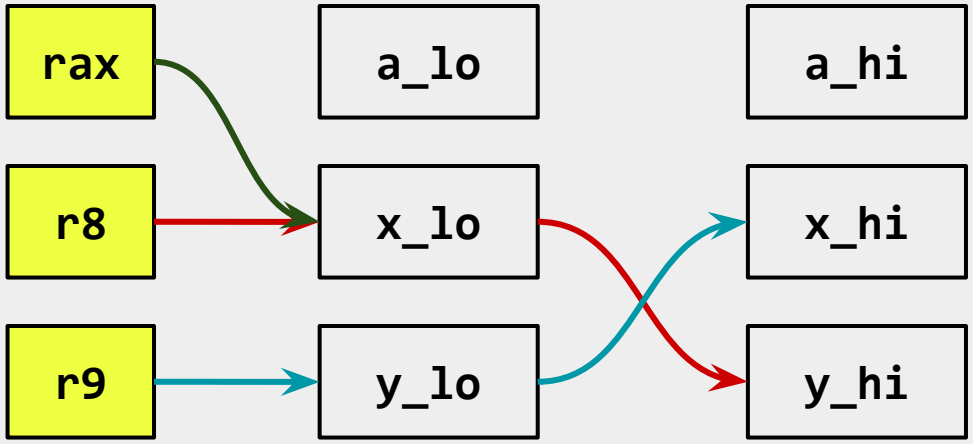
Scenario: A4

```
global mac

section .text

; rdi: a
; rsi: x
; rdx: y

mac:
    mov  r8, [rsi]
    mov  r9, [rdx]
    imul r8, [rdx + 8]
    imul r9, [rsi + 8]
    mov  rax, [rsi]
```



Scenario: A4

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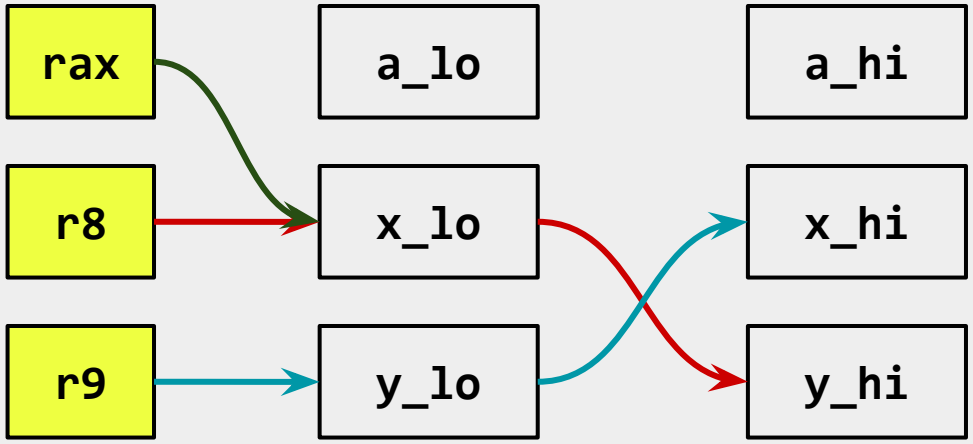
global mac

section .text

; rdi: a
; rsi: x
; rdx: y

mac:
    mov  r8, [rsi]
    mov  r9, [rdx]
    imul r8, [rdx + 8]
    imul r9, [rsi + 8]
    mov  rax, [rsi]
    mul  qword [rdx]
```



https://c9x.me/x86/html/file_module_x86_id_210.html

Scenario: A4

```
global mac

section .text

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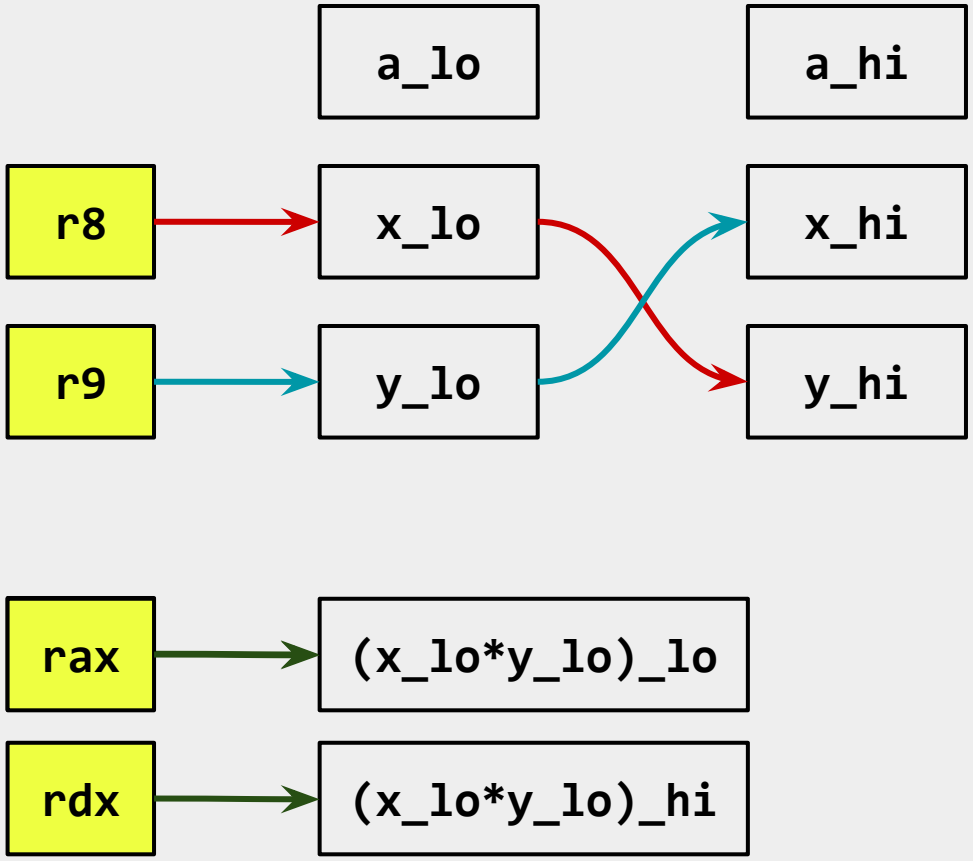
; rsi: x
; rdx: y

mac:
    mov  r8, [rsi]
    mov  r9, [rdx]
    imul r8, [rdx + 8]
    imul r9, [rsi + 8]
    mov  rax, [rsi]
    mul  qword [rdx]
```



https://c9x.me/x86/html/file_module_x86_id_210.html

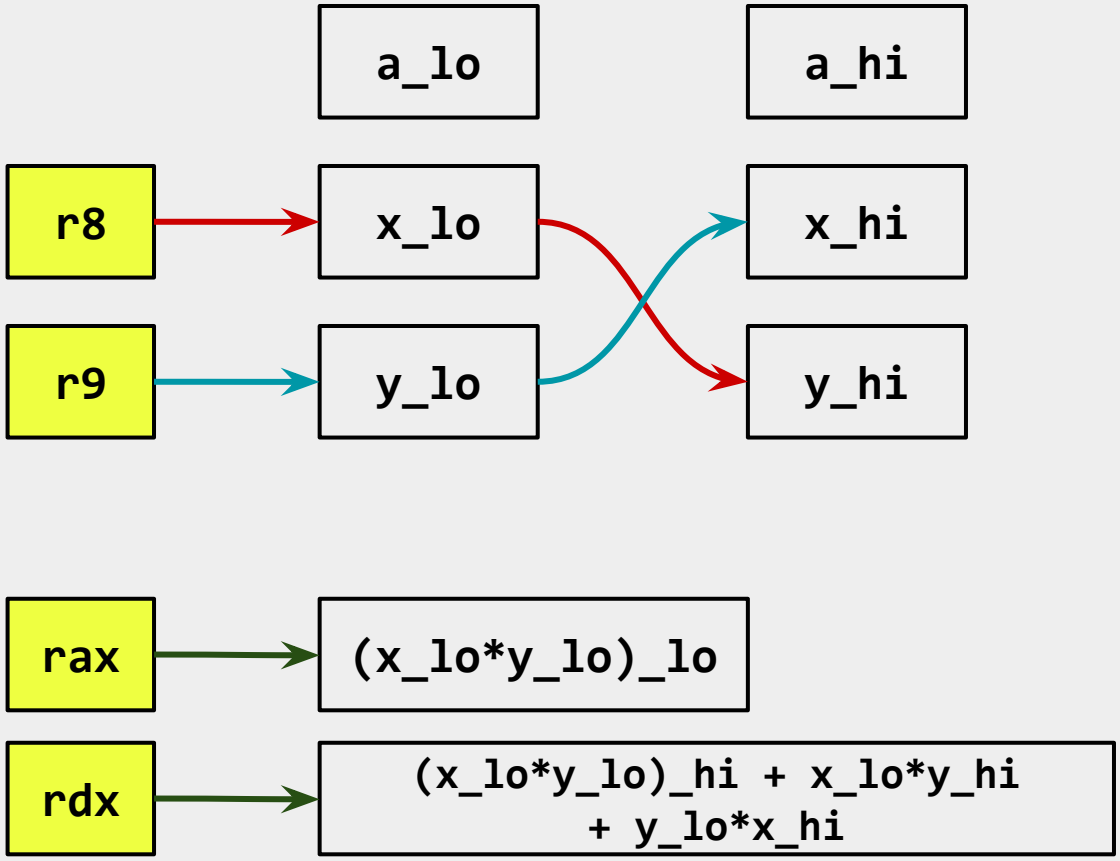
Scenario: A4

```
global mac

section .text

; rdi: a
; rsi: x
; rdx: y

mac:
    mov  r8, [rsi]
    mov  r9, [rdx]
    imul r8, [rdx + 8]
    imul r9, [rsi + 8]
    mov  rax, [rsi]
    mul  qword [rdx]
    add  rdx, r8
    add  rdx, r9
```



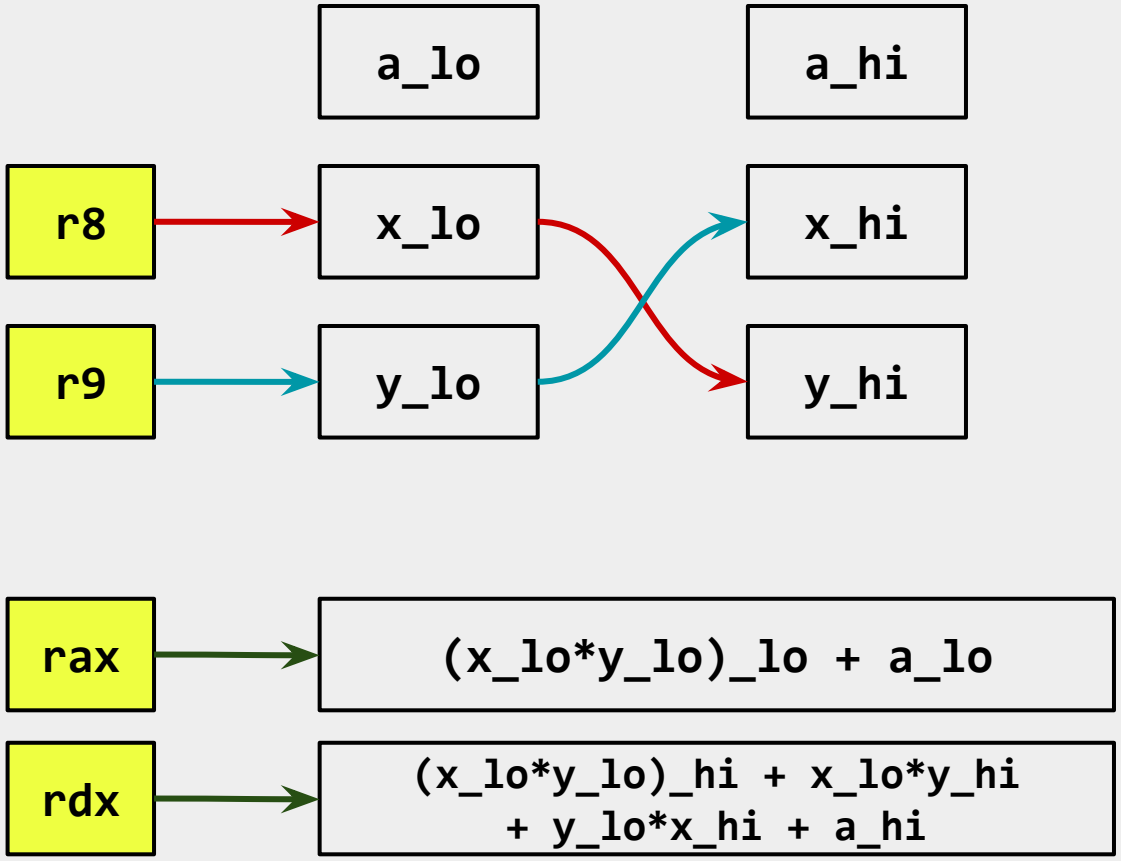
Scenario: A4

```
global mac

section .text

; rdi: a
; rsi: x
; rdx: y

mac:
    mov  r8, [rsi]
    mov  r9, [rdx]
    imul r8, [rdx + 8]
    imul r9, [rsi + 8]
    mov  rax, [rsi]
    mul  qword [rdx]
    add  rdx, r8
    add  rdx, r9
    add  rax, [rdi]
    adc  rdx, [rdi + 8]
```



Scenario: A5

```
void foo(void) {
    int i;
    for (i = 0; i < 100; ++i)
        bar(i);
}
```

```
push rbx
xor ebx,ebx
nop
mov edi,ebx
add ebx,0x1
call 0x0
cmp ebx,0x64
jne 0xf1 ;skok o -15 bajtów, do 0x8
pop rbx
ret
```

Scenario: A5

```
void foo(void) {
    int i;
    for (i = 0; i < 100; ++i)
        bar(i);
}
```

```
push rbx
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ret
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Scenario: A5

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    int i;
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        bar(i);
}
```

```
push rbx
xor ebx,ebx
nop
mov edi,ebx
add ebx,0x1
call 0x0
cmp ebx,0x64
jne 0xf1 ;skok o -15 bajtów, do 0x8
pop rbx
ret
```

Co w tym przypadku robi instrukcja xor?

Scenario: A5

```
void foo(void) {
    int i;
    for (i = 0; i < 100; ++i)
        bar(i);
}
```

```
push rbx
xor ebx,ebx
nop
mov edi,ebx
add ebx,0x1
call 0x0
cmp ebx,0x64
jne 0xf1 ;skok o -15 bajtów, do 0x8
pop rbx
ret
```

Co w tym przypadku robi instrukcja xor?

Zeruje rejestr rbx.

Scenario: A5

```
void foo(void) {
    int i;
    for (i = 0; i < 100; ++i)
        bar(i);
}
```

```
push rbx
xor ebx,ebx
nop
mov edi,ebx
add ebx,0x1
call 0x0
cmp ebx,0x64
jne 0xf1 ;skok o -15 bajtów, do 0x8
pop rbx
ret
```

Po co jest nam instrukcja nop?

Scenario: A5

```
void foo(void) {
    int i;
    for (i = 0; i < 100; ++i)
        bar(i);
}
```

```
push rbx
xor ebx,ebx
nop
mov edi,ebx
add ebx,0x1
call 0x0
cmp ebx,0x64
jne 0xf1 ;skok o -15 bajtów, do 0x8
pop rbx
ret
```

Po co jest nam instrukcja nop?

Wyrównuje adres docelowy skoku (instrukcja jne).

Scenario: A5

```
void foo(void) {
    int i;
    for (i = 0; i < 100; ++i)
        bar(i);
}
```

```
push rbx
xor ebx,ebx
nop
mov edi,ebx
add ebx,0x1
call 0x0
cmp ebx,0x64
jne 0xf1 ;skok o -15 bajtów, do 0x8
pop rbx
ret
```

Dlaczego przepisujemy ebx na edi?

Scenario: A5

```
void foo(void) {
    int i;
    for (i = 0; i < 100; ++i)
        bar(i);
}
```

```
push rbx
xor ebx,ebx
nop
mov edi,ebx
add ebx,0x1
call 0x0
cmp ebx,0x64
jne 0xf1 ;skok o -15 bajtów, do 0x8
pop rbx
ret
```

Dlaczego przepisujemy ebx na edi?

Bo pierwszy argument funkcji jest przekazywany w rejestrze rdi.

Scenario: A5

```
void foo(void) {
    int i;
    for (i = 0; i < 100; ++i)
        bar(i);
}
```

```
push rbx
xor ebx,ebx
nop
mov edi,ebx
add ebx,0x1
call 0x0
cmp ebx,0x64
jne 0xf1 ;skok o -15 bajtów, do 0x8
pop rbx
ret
```

Dlaczego iterujemy po ebx?

Scenario: A5

```
void foo(void) {
    int i;
    for (i = 0; i < 100; ++i)
        bar(i);
}
```

```
push rbx
xor ebx,ebx
nop
mov edi,ebx
add ebx,0x1
call 0x0
cmp ebx,0x64
jne 0xf1 ;skok o -15 bajtów, do 0x8
pop rbx
ret
```

Dlaczego iterujemy po ebx?

Bo ebx nie zostanie zmodyfikowany przez bar.

Scenario: A6

Napisz w asemblerze program *hello world*.

```
global _start

section .rodata                         ; dane tylko do odczytu
hello    db "Hello World!"
```

Scenario: A6

Napisz w asemblerze program *hello world*.

```
NEW_LINE  equ 10

global _start

section .rodata                     ; dane tylko do odczytu
hello    db "Hello World!"
new_line db NEW_LINE
```

Scenario: A6

Napisz w asemblerze program *hello world*.

```
NEW_LINE  equ 10

global _start

section .rodata                         ; dane tylko do odczytu
hello    db "Hello World!"
new_line db NEW_LINE

section .text                           ; kod wykonywalny
_start:
```

Scenario: A6

Napisz w asemblerze program *hello world*.

```
SYS_WRITE equ 1

STDOUT    equ 1
NEW_LINE  equ 10

global _start

section .rodata                         ; dane tylko do odczytu
hello    db "Hello World!"
new_line db NEW_LINE

section .text                           ; kod wykonywalny
_start:
     mov eax, SYS_WRITE
     mov edi, STDOUT
```

Scenario: A6

Napisz w asemblerze program *hello world*.

```
SYS_WRITE equ 1

STDOUT    equ 1
NEW_LINE  equ 10

global _start

section .rodata                         ; dane tylko do odczytu
hello    db "Hello World!"
new_line db NEW_LINE

section .text                           ; kod wykonywalny
_start:
     mov eax, SYS_WRITE
     mov edi, STDOUT
     mov rsi, hello
     mov edx, new_line - hello + 1
     syscall
```

Scenario: A6

Napisz w asemblerze program *hello world*.

```
SYS_WRITE equ 1
SYS_EXIT  equ 60
STDOUT    equ 1
NEW_LINE  equ 10

global _start

section .rodata                         ; dane tylko do odczytu
hello    db "Hello World!"
new_line db NEW_LINE

section .text                           ; kod wykonywalny
_start:
     mov eax, SYS_WRITE
     mov edi, STDOUT
     mov rsi, hello
     mov edx, new_line - hello + 1
     syscall
     mov eax, SYS_EXIT
     xor edi, edi
     syscall
```

Scenario: A6

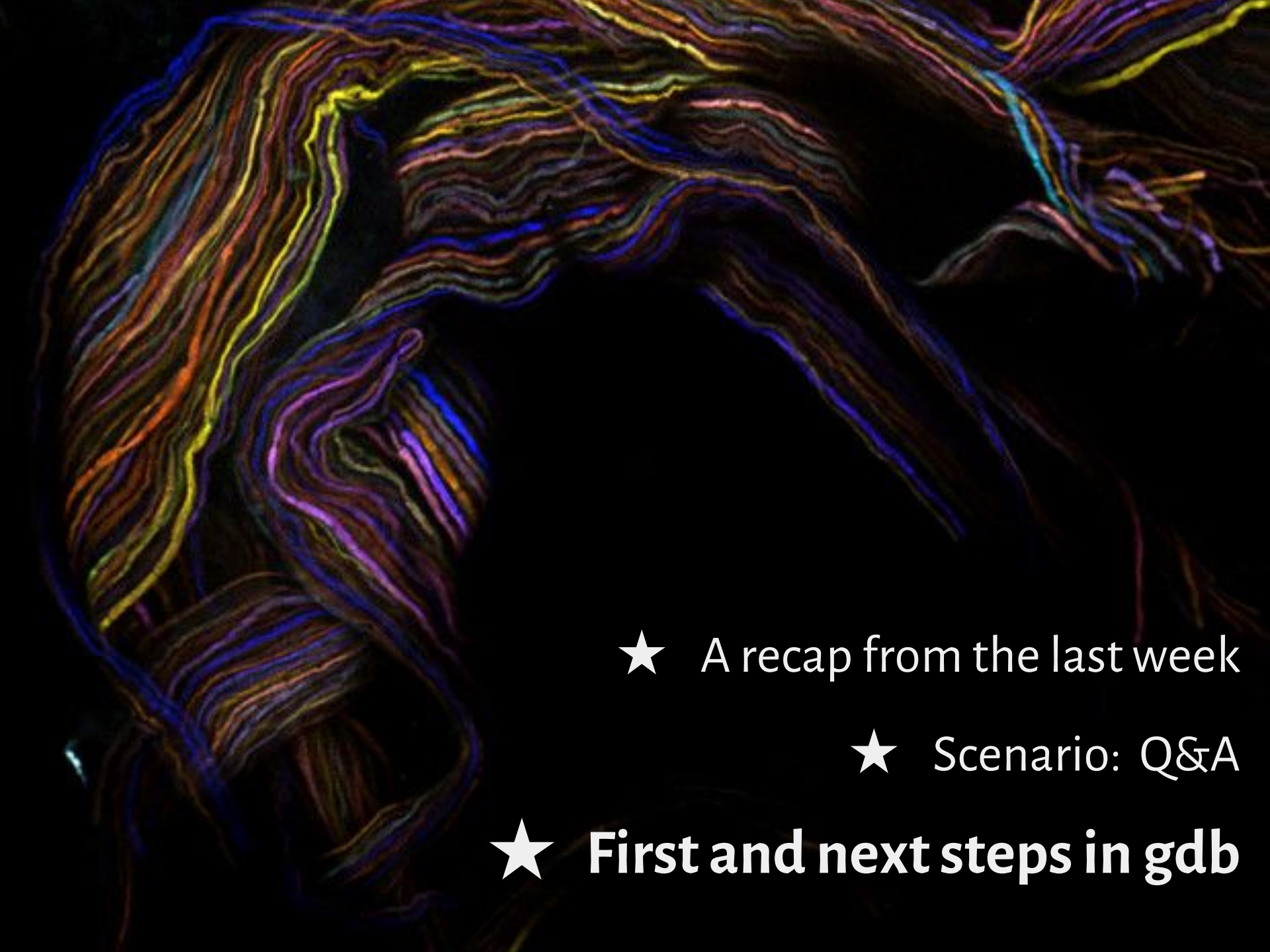
Napisz w asemblerze program *hello world*.

```
SYS_WRITE equ 1
SYS_EXIT  equ 60
STDOUT    equ 1
NEW_LINE  equ 10

global _start

section .rodata                         ; dane tylko do odczytu
hello    db "Hello World!"
new_line db NEW_LINE

section .text                           ; kod wykonywalny
_start:
     mov eax, SYS_WRITE
     mov edi, STDOUT
     mov rsi, hello
     mov edx, new_line - hello + 1
     syscall
     mov eax, SYS_EXIT
     xor edi, edi
     syscall
```



★ A recap from the last week

★ Scenario: Q&A

★ **First and next steps in gdb**

Let us see... gdb

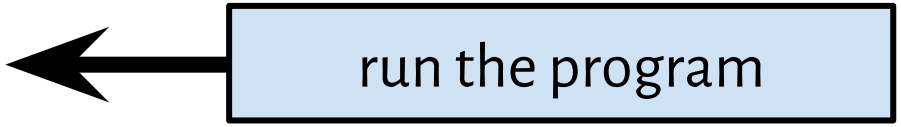
```
$ nasm -f elf64 -F dwarf -g hello.asm -o hello

$ ld -o hello hello.o

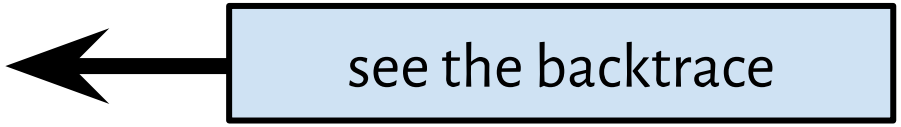
$ gdb --args hello 1 2 3 4
```

```
(gdb) b 28
```


```
(gdb) r
```




```
(gdb) bt
```



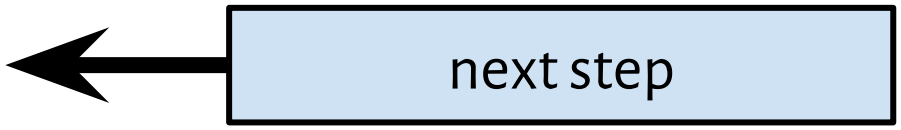
Let us see... gdb

```
$ nasm -f elf64 -F dwarf -g hello.asm -o hello

$ ld -o hello hello.o

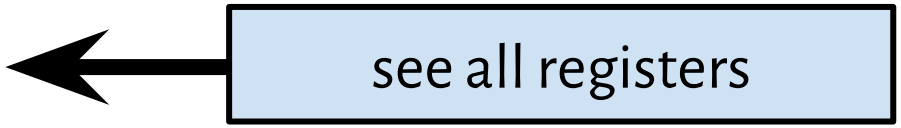
$ gdb --args hello 1 2 3 4
```

```
(gdb) si
```




```
(gdb) p $rsi
```


```
(gdb) i r
```



Let us see... gdb

```
$ nasm -f elf64 -F dwarf -g hello.asm -o hello

$ ld -o hello hello.o

$ gdb --args hello 1 2 3 4
```

```
(gdb) p *(char *) [addr]
```

print a char

```
(gdb) x/s [addr]
```

examine a string

```
(gdb) info symbol [addr]
```

find the nearest symbol

Assignment #1

Expected in:

https://svn.mimuw.edu.pl/repos/SO/studenci/<login>/zadanie1

with a proper filename and no additional files

Expected by:

22 March 2019, 8 p.m.

Assignment #1

- ★ Registers should be zeroed: https://github.com/hjl-tools/x86-psABI/wiki/X86-psABI
- ★ The opened file does not need to be closed.
- ★ Sequences similar to 6,8,0,6,8,0,2,0 should be detected.