CPSC 240: Computer Organization and Assembly Language
Assignment 04, Fall Semester 2024

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Programming:

1. Download the "CPSC-240 Assignment04.docx" document.
2. Design "multiple.asm" program to implement an if-else structure in assembly language, and use assembly language to realize the function of the following C++ instructions. NOTE: variable sizes and program functions should be equivalent to C/C++ instructions.

```
unsigned short num = 65535;                    // use dw to declare 16-bit variable
unsigned short mul_3 = 0, other = 0;           // use dw to declare 16-bit variable
if(num % 3 == 0 && num % 5 != 0) {
        mul_3++;
} else {
        other++;
}
```

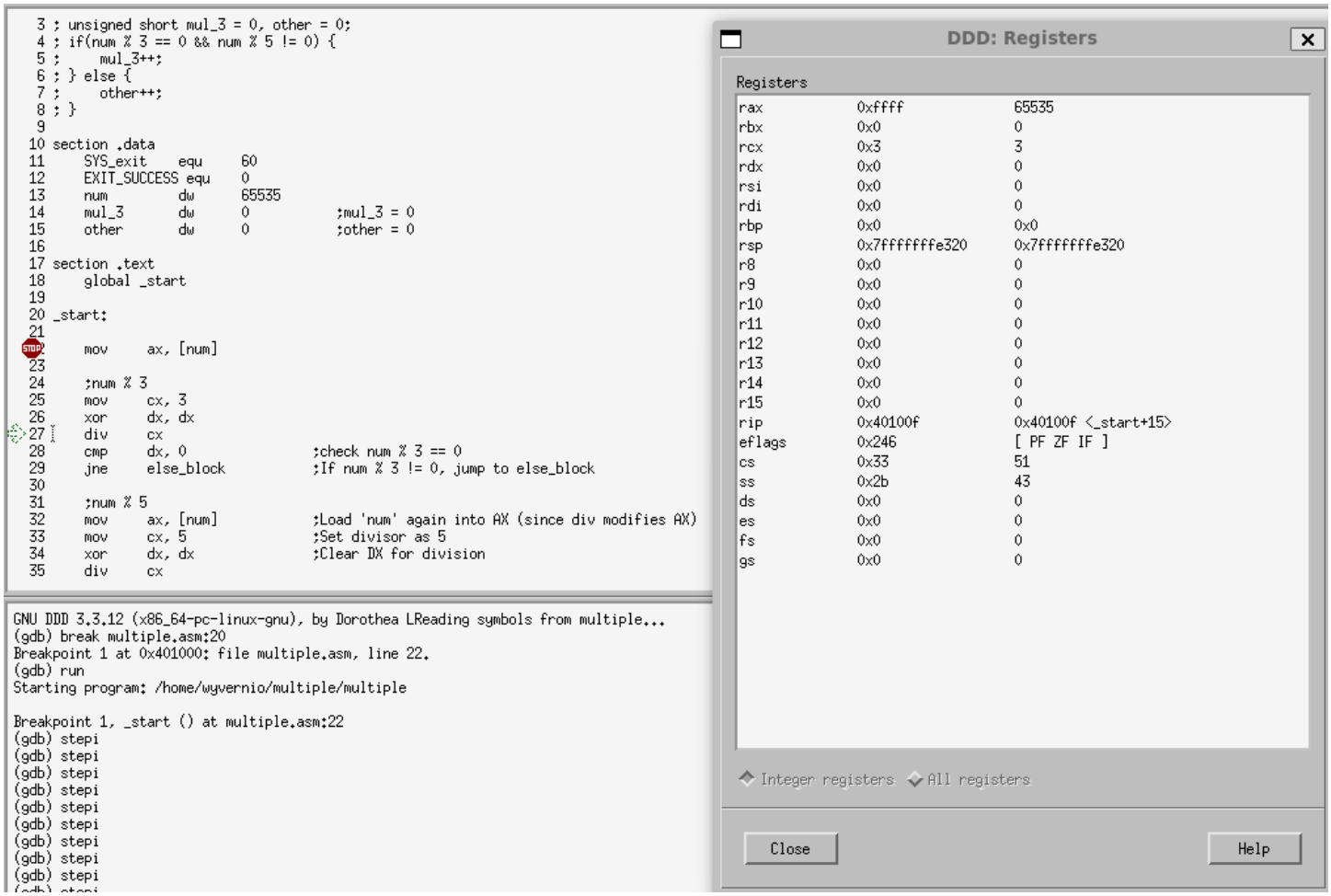
3. Assemble the "multiple.asm" file and link the "multiple.o" file to get the "multiple" executable file.
4. Run the "multiple" file with the GDB debugger to display the memory of num, as well as the simulation results of mul_3 and other.
5. Insert source code (multiple.asm) and simulation results (GDB window) of the memory (num, mul_3, and other) in the document. Write an analysis to verify simulation results.
6. Save the file in pdf format and submit the pdf file to Canvas before the deadline.

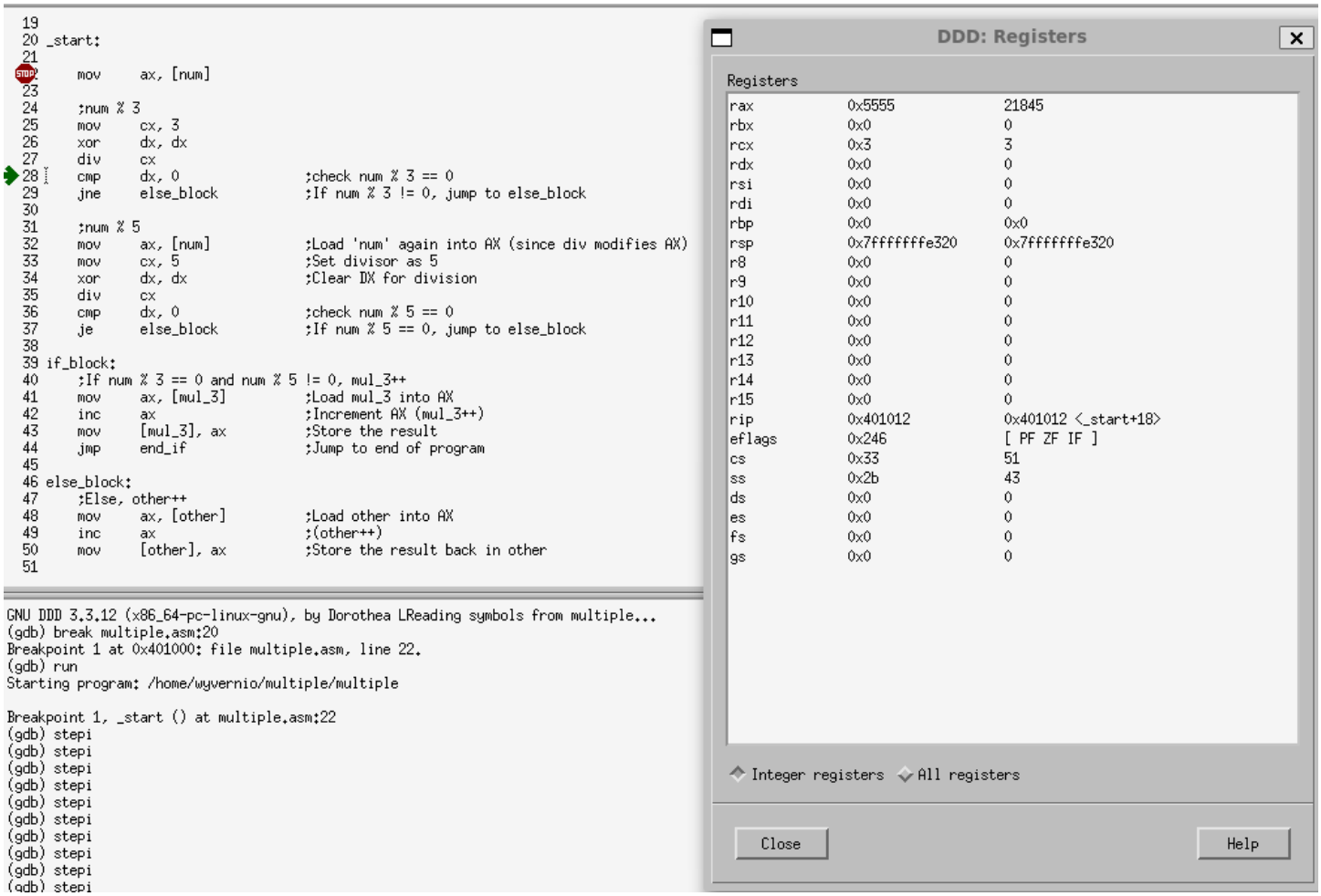
```
[; multiple.asm
; unsigned short num = 65535;
; unsigned short mul_3 = 0, other = 0;
; if(num % 3 == 0 && num % 5 != 0) {
;         mul_3++;
; } else {
;         other++;
; }

section .data
        SYS_exit        equ         60
        EXIT_SUCCESS equ        0
        num             dw          65535
        mul_3           dw          0               ;mul_3 = 0
        other           dw          0               ;other = 0
```

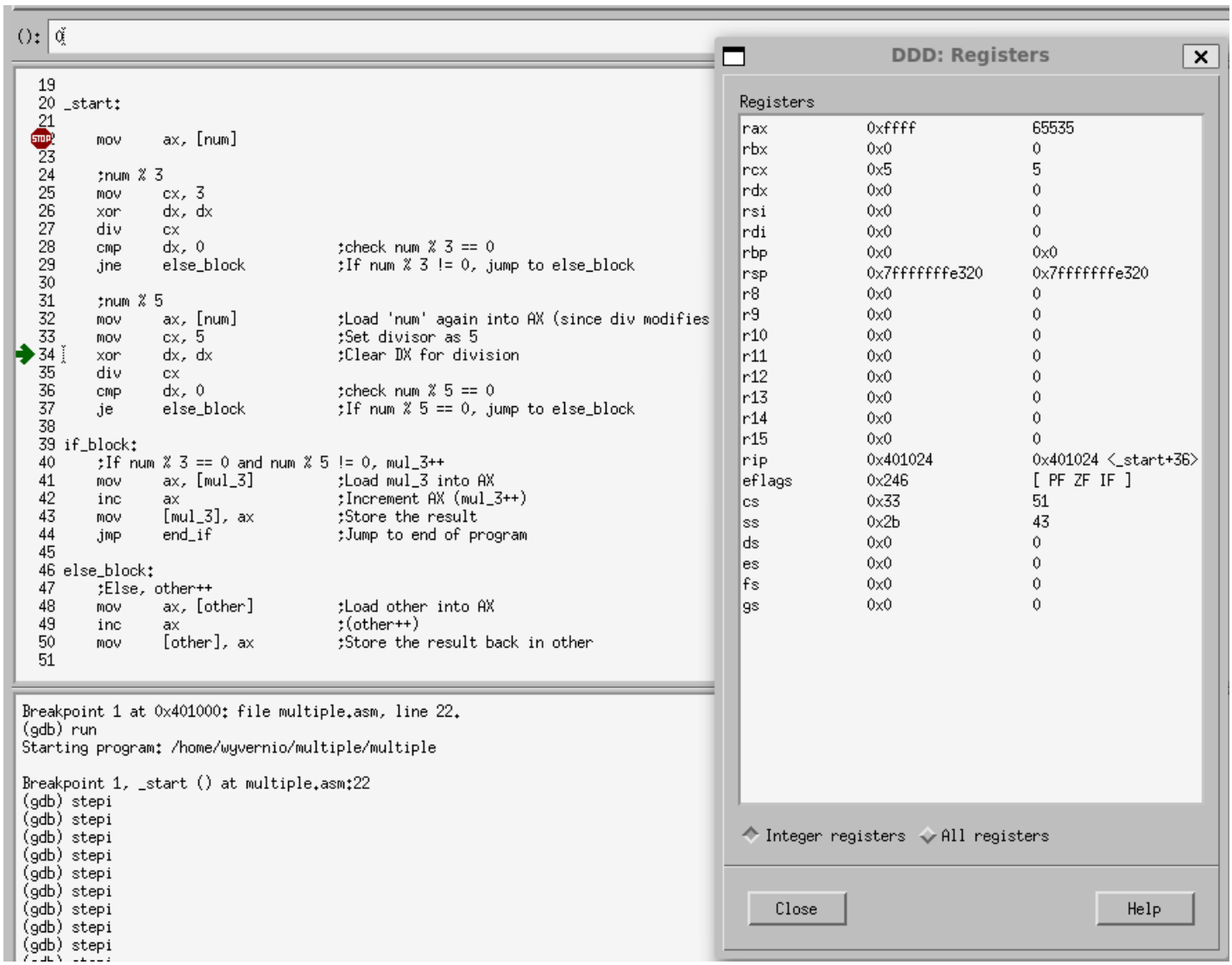
```
section .text
    global _start

_start:

    mov     ax, [num]

    ;num % 3
    mov     cx, 3
    xor     dx, dx
    div     cx
    cmp     dx, 0                   ;check num % 3 == 0
    jne     else_block              ;If num % 3 != 0, jump to else_block

    ;num % 5
    mov     ax, [num]               ;Load 'num' again into AX (since div modifies AX)
    mov     cx, 5                   ;Set divisor as 5
    xor     dx, dx                  ;Clear DX for division
    div     cx
    cmp     dx, 0                   ;check num % 5 == 0
    je      else_block              ;If num % 5 == 0, jump to else_block

if_block:
    ;If num % 3 == 0 and num % 5 != 0, mul_3++
    mov     ax, [mul_3]             ;Load mul_3 into AX
    inc     ax                      ;Increment AX (mul_3++)
    mov     [mul_3], ax             ;Store the result
    jmp     end_if                  ;Jump to end of program

else_block:
    ;Else, other++
    mov     ax, [other]             ;Load other into AX
    inc     ax                      ;(other++)
    mov     [other], ax             ;Store the result back in other

end_if:
    ; Exit
    mov     rax, SYS_exit
    mov     rdi, EXIT_SUCCESS
```

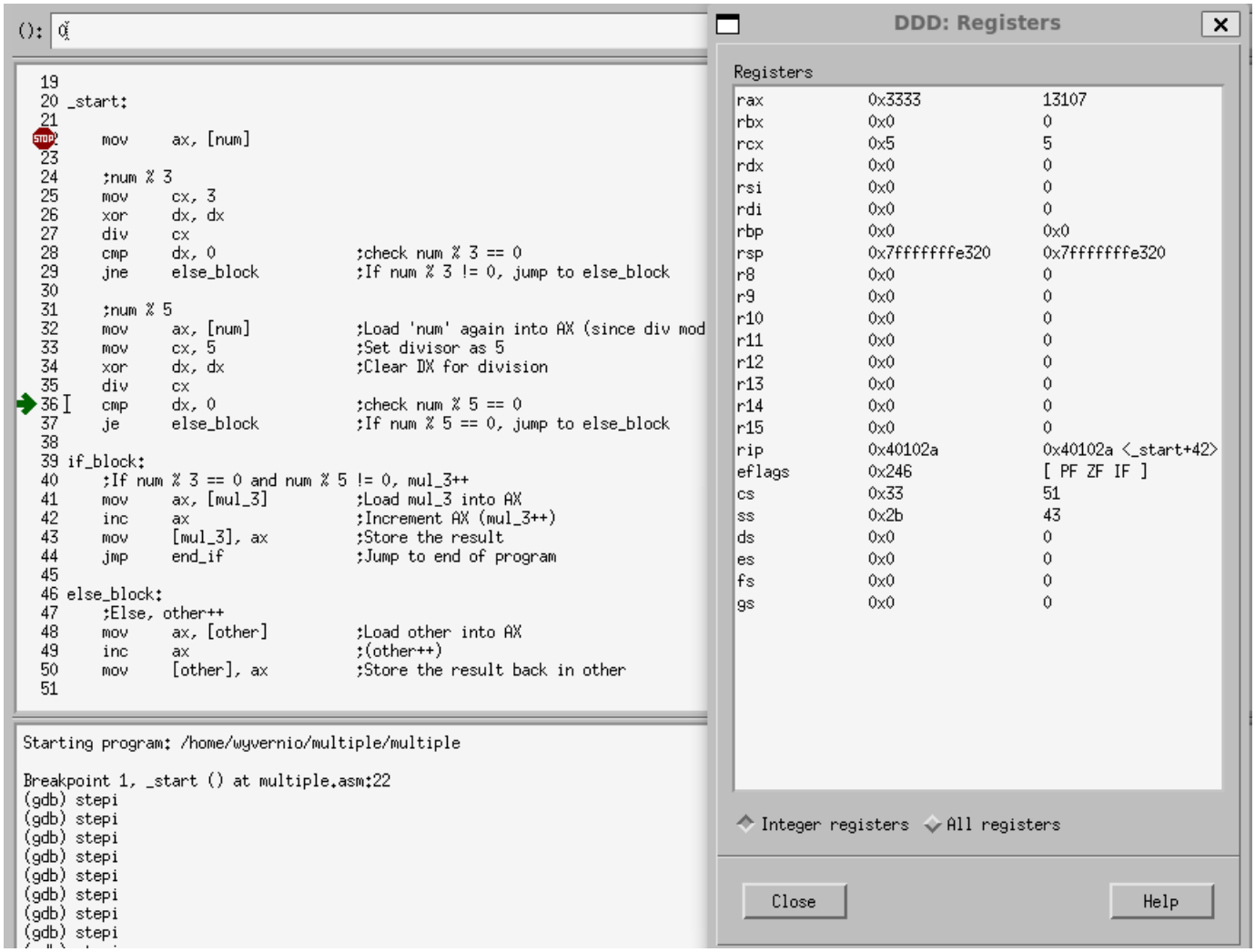
syscall ;terminate]

[In this spot, I'm going to insert screenshots of the changed in my register to show the values changing correctly according to which step of the program we're currently at. Then finish off with the value of num.

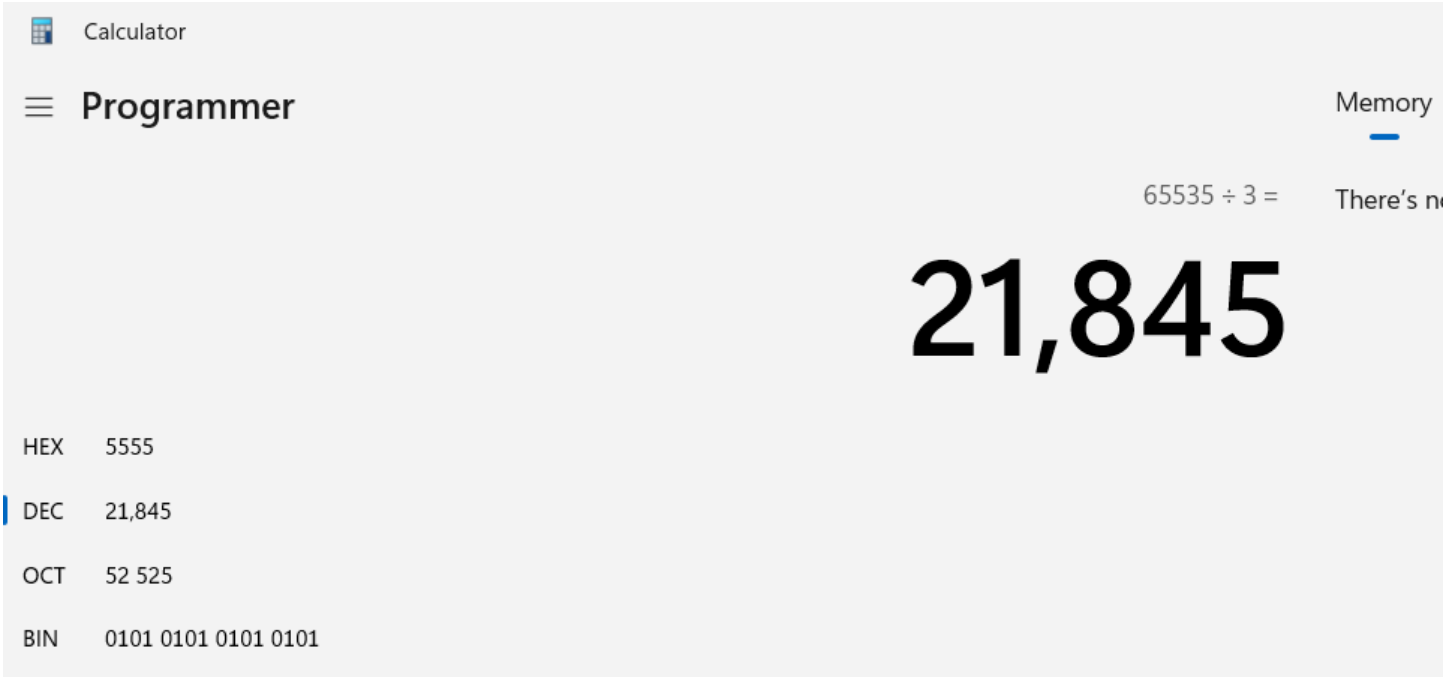



19
20 _start:
21
22 mov ax, [num]
23
24 ;num % 3
25 mov cx, 3
26 xor dx, dx
27 div cx
28 cmp dx, 0 ;check num % 3 == 0
29 jne else_block ;If num % 3 != 0, jump to else_block
30
31 ;num % 5
32 mov ax, [num] ;Load 'num' again into AX (since div modifies AX)
33 mov cx, 5 ;Set divisor as 5
34 xor dx, dx ;Clear DX for division
35 div cx
36 cmp dx, 0 ;check num % 5 == 0
37 je else_block ;If num % 5 == 0, jump to else_block
38
39 if_block:
40 ;If num % 3 == 0 and num % 5 != 0, mul_3++
41 mov ax, [mul_3] ;Load mul_3 into AX
42 inc ax ;Increment AX (mul_3++)
43 mov [mul_3], ax ;Store the result
44 jmp end_if ;Jump to end of program
45
46 else_block:
47 ;Else, other++
48 mov ax, [other] ;Load other into AX
49 inc ax ;(other++)
50 mov [other], ax ;Store the result back in other
51
GNU DDD 3.3.12 (x86_64-pc-linux-gnu), by Dorothea LReading symbols from multiple...
(gdb) break multiple.asm:20
Breakpoint 1 at 0x401000: file multiple.asm, line 22.
(gdb) run
Starting program: /home/wyvernio/multiple/multiple
Breakpoint 1, _start () at multiple.asm:22
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
DDD: Registers
Registers
rax 0x5555 21845
rbx 0x0 0
rcx 0x3 3
rdx 0x0 0
rsi 0x0 0
rdi 0x0 0
rbp 0x0 0x0
rsp 0x7fffffffe320 0x7fffffffe320
r8 0x0 0
r9 0x0 0
r10 0x0 0
r11 0x0 0
r12 0x0 0
r13 0x0 0
r14 0x0 0
r15 0x0 0
rip 0x401012 0x401012 <_start+18>
eflags 0x246 [PF ZF IF]
cs 0x33 51
ss 0x2b 43
ds 0x0 0
es 0x0 0
fs 0x0 0
gs 0x0 0
Integer registers
All registers
Close
Help


():
19
20 _start:
21
22 mov ax, [num]
23
24 ;num % 3
25 mov cx, 3
26 xor dx, dx
27 div cx
28 cmp dx, 0 ;check num % 3 == 0
29 jne else_block ;If num % 3 != 0, jump to else_block
30
31 ;num % 5
32 mov ax, [num] ;Load 'num' again into AX (since div modifies
33 mov cx, 5 ;Set divisor as 5
34 xor dx, dx ;Clear DX for division
35 div cx
36 cmp dx, 0 ;check num % 5 == 0
37 je else_block ;If num % 5 == 0, jump to else_block
38
39 if_block:
40 ;If num % 3 == 0 and num % 5 != 0, mul_3++
41 mov ax, [mul_3] ;Load mul_3 into AX
42 inc ax ;Increment AX (mul_3++)
43 mov [mul_3], ax ;Store the result
44 jmp end_if ;Jump to end of program
45
46 else_block:
47 ;Else, other++
48 mov ax, [other] ;Load other into AX
49 inc ax ;(other++)
50 mov [other], ax ;Store the result back in other
51
Breakpoint 1 at 0x401000: file multiple.asm, line 22.
(gdb) run
Starting program: /home/wyvernio/multiple/multiple
Breakpoint 1, _start () at multiple.asm:22
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
DDD: Registers
Registers
rax 0xffff 65535
rbx 0x0 0
rcx 0x5 5
rdx 0x0 0
rsi 0x0 0
rdi 0x0 0
rbp 0x0 0x0
rsp 0x7fffffffe320 0x7fffffffe320
r8 0x0 0
r9 0x0 0
r10 0x0 0
r11 0x0 0
r12 0x0 0
r13 0x0 0
r14 0x0 0
r15 0x0 0
rip 0x401024 0x401024 <_start+36>
eflags 0x246 [PF ZF IF]
cs 0x33 51
ss 0x2b 43
ds 0x0 0
es 0x0 0
fs 0x0 0
gs 0x0 0
Integer registers
All registers
Close
Help



65535 / 3 is = 21845, as evidenced by this calculator.



Our other answer is also correct, as well as the remainder being 0 for both num % 3 and num % 5, as 65535 is divisible by both 3 and 5 respectively, meaning it cannot have a remainder.

And below this section is the section with the result of mul_3 and other, where you can find the final register proof.

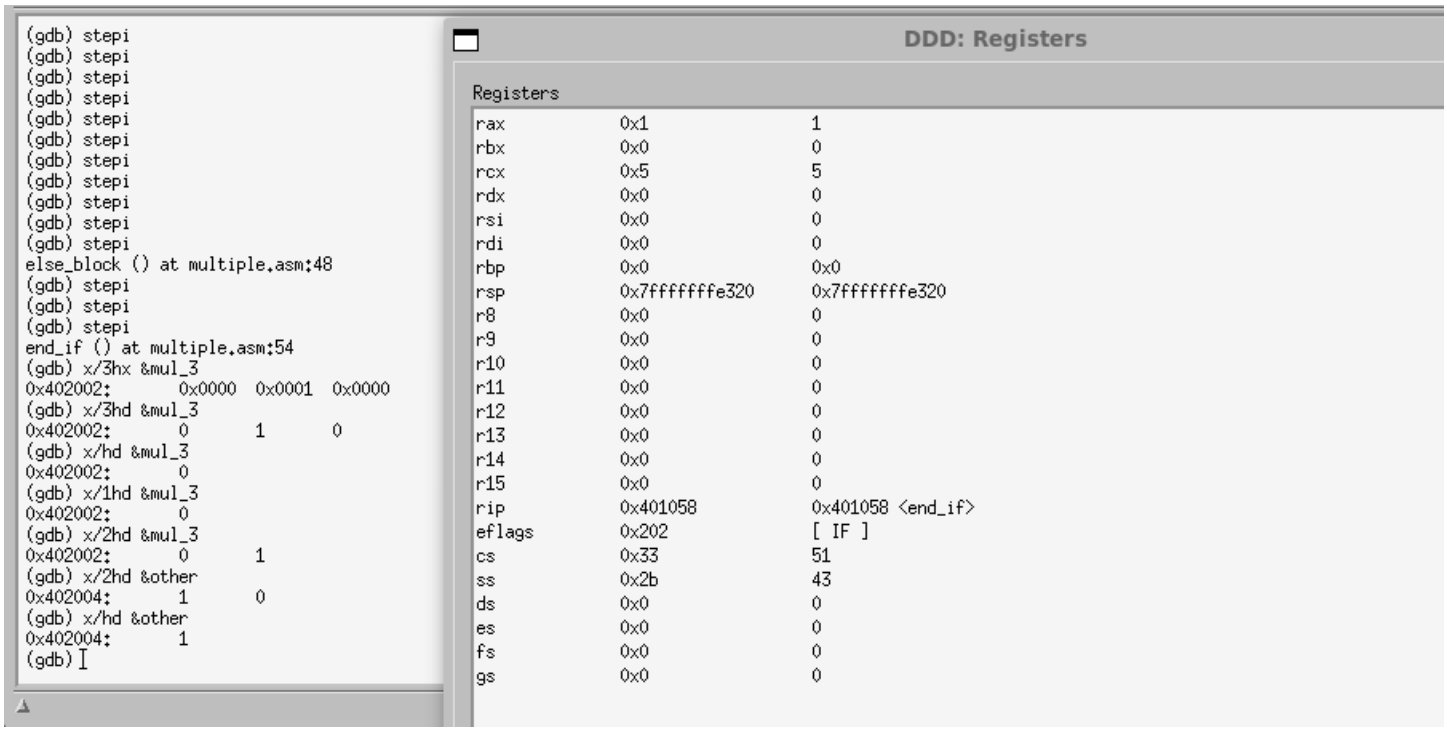
Here is num in both hexadecimal and decimal. 😊

```
 25     mov     cx, 3
 26     xor     dx, dx
 27     div     cx
 28     cmp     dx, 0               ;check num % 3 == 0
 29     jne     else_block          ;If num % 3 != 0, jump to else_block
 30
 31     ;num % 5
 32     mov     ax, [num]           ;Load 'num' again into AX (since div modifies AX)
 33     mov     cx, 5               ;Set divisor as 5
 34     xor     dx, dx              ;Clear DX for division
 35     div     cx
 36     cmp     dx, 0               ;check num % 5 == 0
 37     je      else_block          ;If num % 5 == 0, jump to else_block
 38
 39 if_block:
 40     ;If num % 3 == 0 and num % 5 != 0, mul_3++
 41     mov     ax, [mul_3]         ;Load mul_3 into AX
 42     inc     ax                  ;Increment AX (mul_3++)
 43     mov     [mul_3], ax         ;Store the result
 44     jmp     end_if              ;Jump to end of program
 45
 46 else_block:
 47     ;Else, other++
 48     mov     ax, [other]         ;Load other into AX
 49     inc     ax                  ;(other++)
 50     mov     [other], ax         ;Store the result back in other
 51
 52 end_if:
 53     ; Exit
 54     mov     rax, SYS_exit
 55     mov     rdi, EXIT_SUCCESS
 56     syscall                     ;terminate
 57
```

```
else_block () at multiple.asm:48
(gdb) run
Starting program: /home/wyvernio/multiple/multiple

Breakpoint 1, _start () at multiple.asm:22
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
(gdb) stepi
else_block () at multiple.asm:48
(gdb) stepi
(gdb) stepi
(gdb) stepi
end_if () at multiple.asm:54
(gdb) x/hd &num
0x402000:       -1
(gdb) x/3hx &num
0x402000:       0xffff  0x0000  0x0001
(gdb) x/3hd &num
0x402000:       -1      0       1
```

]

[



The reason why mul_3 is 0 is because mul_3's conditions were not entirely fulfilled, num % 3 has to = 0 and num % 5 had to != 0, and since this was not true, mul_3 returns as false, or 0.

This is further evidenced by "other" being equal to 1, as this means that the else section under num % 5 was executed, meaning that that the remainder of num being divided by 5 was 0.

Therefore, num % 5 = 0 was the reason why both mul_3 is 0 and other is 1.]