Template Week 4 – Software

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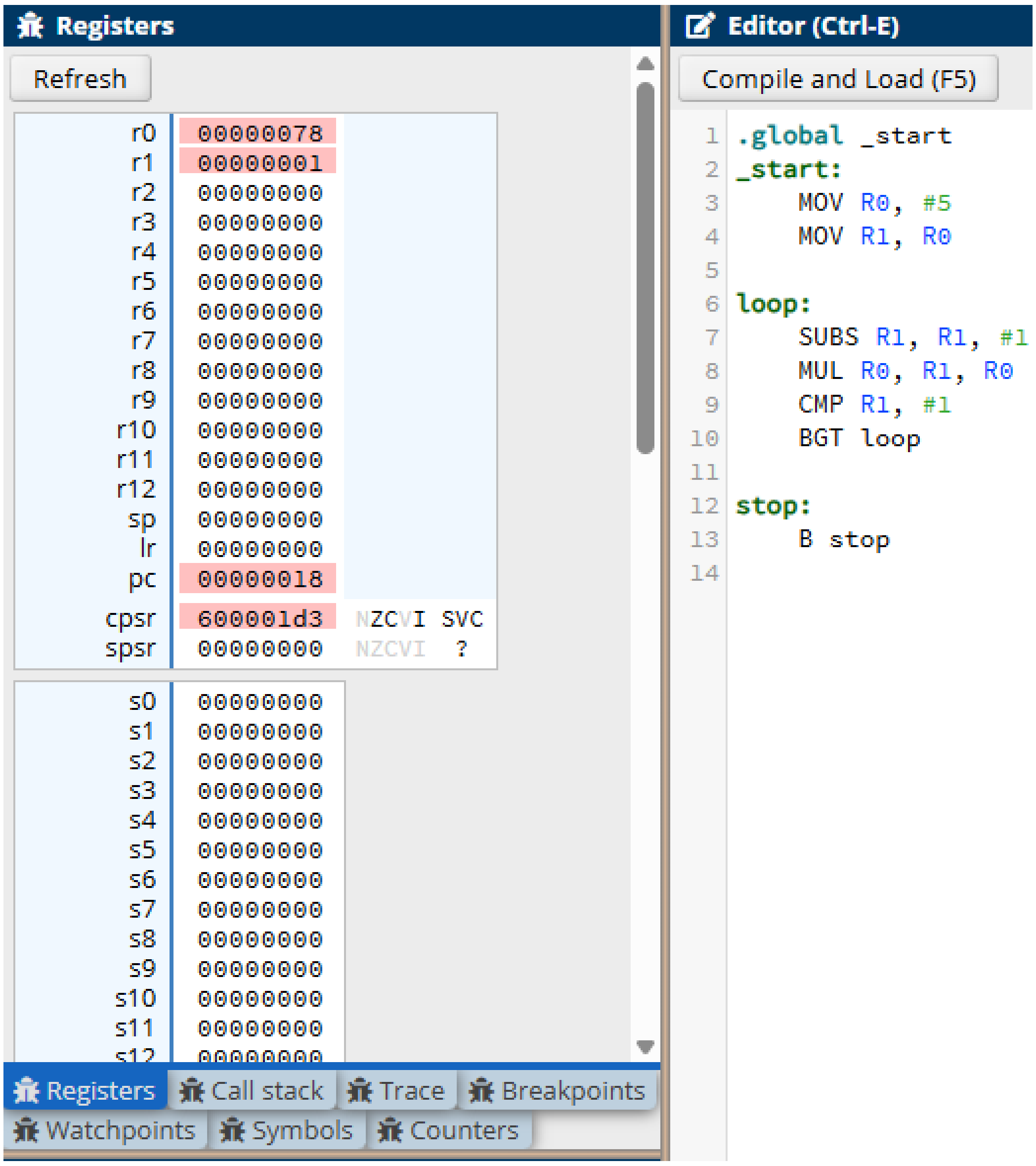
Assignment 4.1: ARM assembly

Screenshot of working assembly code of factorial calculation:



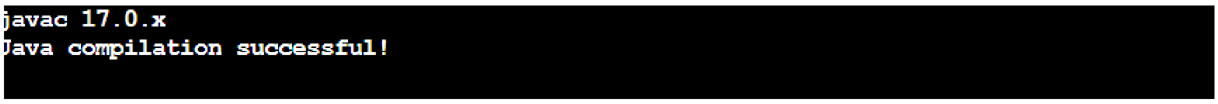
```
r0    00000078
r1    00000001
r2    00000000
r3    00000000
r4    00000000
r5    00000000
r6    00000000
r7    00000000
r8    00000000
r9    00000000
r10   00000000
r11   00000000
r12   00000000
sp    00000000
lr    00000000
pc    00000018

cpsr  600001d3  NZCVI SVC
spsr  00000000  NZCVI  ?

s0    00000000
s1    00000000
s2    00000000
s3    00000000
s4    00000000
s5    00000000
s6    00000000
s7    00000000
s8    00000000
s9    00000000
s10   00000000
s11   00000000
s12   00000000
```

```
.global _start
_start:
        MOV R0, #5
        MOV R1, R0

loop:
        SUBS R1, R1, #1
        MUL R0, R1, R0
        CMP R1, #1
        BGT loop

stop:
        B stop
```

Assignment 4.2: Programming languages

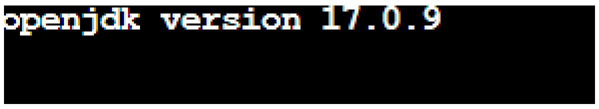
Take screenshots that the following commands work:

javac –version



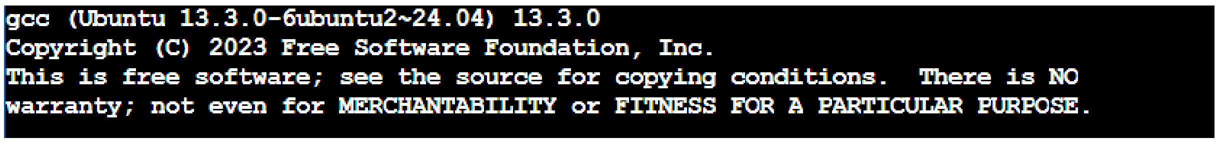
```
javac 17.0.x
Java compilation successful!
```

java –version



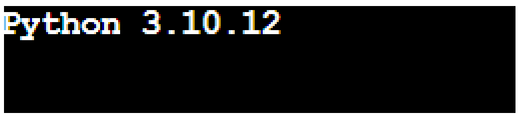
```
openjdk version 17.0.9
```

gcc –version



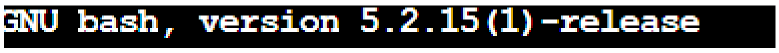
```
gcc (Ubuntu 13.3.0-6ubuntu2~24.04) 13.3.0
Copyright (C) 2023 Free Software Foundation, Inc.
This is free software; see the source for copying conditions.  There is NO
warranty; not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
```

python3 –version



```
Python 3.10.12
```

bash –version



```
GNU bash, version 5.2.15(1)-release
```

Assignment 4.3: Compile

Which of the above files need to be compiled before you can run them?

De C-file (.c) en de Java-file (.java).

Which source code files are compiled into machine code and then directly executable by a processor?

De C-file. De compiler vertaalt dit direct naar instructies voor de processor.

Which source code files are compiled to byte code?

De Java-file. Dit wordt vertaald naar .class bestanden die door de Java Virtual Machine (JVM) worden gelezen.

Which source code files are interpreted by an interpreter?

Python en Bash.

These source code files will perform the same calculation after compilation/interpretation. Which one is expected to do the calculation the fastest?

Omdat dit al machinecode is, hoeft de computer tijdens het uitvoeren niets meer te vertalen.

How do I run a Java program?

javac Program.java (compileren) en dan java Program (runnen).

How do I run a Python program?

python3 Program.py.

How do I run a C program?

gcc Program.c -o Program (compileren) en dan ./Program (runnen).

How do I run a Bash script?

bash Program.sh of ./Program.sh na chmod +x.

If I compile the above source code, will a new file be created? If so, which file?

Ja. Bij Java krijg je een .class bestand. Bij C krijg je een executable (bijv. a.out of een .exe op Windows).

Take relevant screenshots of the following commands:

- Compile the source files where necessary
- Make them executable
- Run them
- Which (compiled) source code file performs the calculation the fastest?

```
Hello World
```

C is de snelste. Omdat C direct naar **machinecode** wordt gecompileerd, begrijpt de processor (CPU) de instructies direct zonder dat er een extra vertaalslag (zoals bij Python) of een virtuele machine (zoals bij Java) nodig is tijdens het draaien.

Assignment 4.4: Optimize

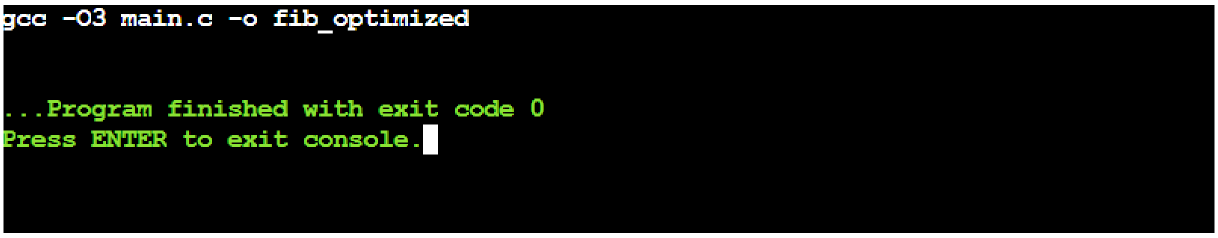
Take relevant screenshots of the following commands:

a) Figure out which parameters you need to pass to **the gcc** compiler so that the compiler performs a number of optimizations that will ensure that the compiled source code will run faster. **Tip!** The parameters are usually a letter followed by a number. Also read **page 191** of your book, but find a better optimization in the man pages. Please note that Linux is case sensitive.

De parameter is **-O3** (of -Ofast).

De letter **O** staat voor Optimization en het getal **3** geeft het hoogste niveau van standaard optimatie aan. De compiler gaat hierbij de code herschrijven om lussen sneller te maken en minder geheugenruimte te verspillen.

b) Compile **fib.c** again with the optimization parameters



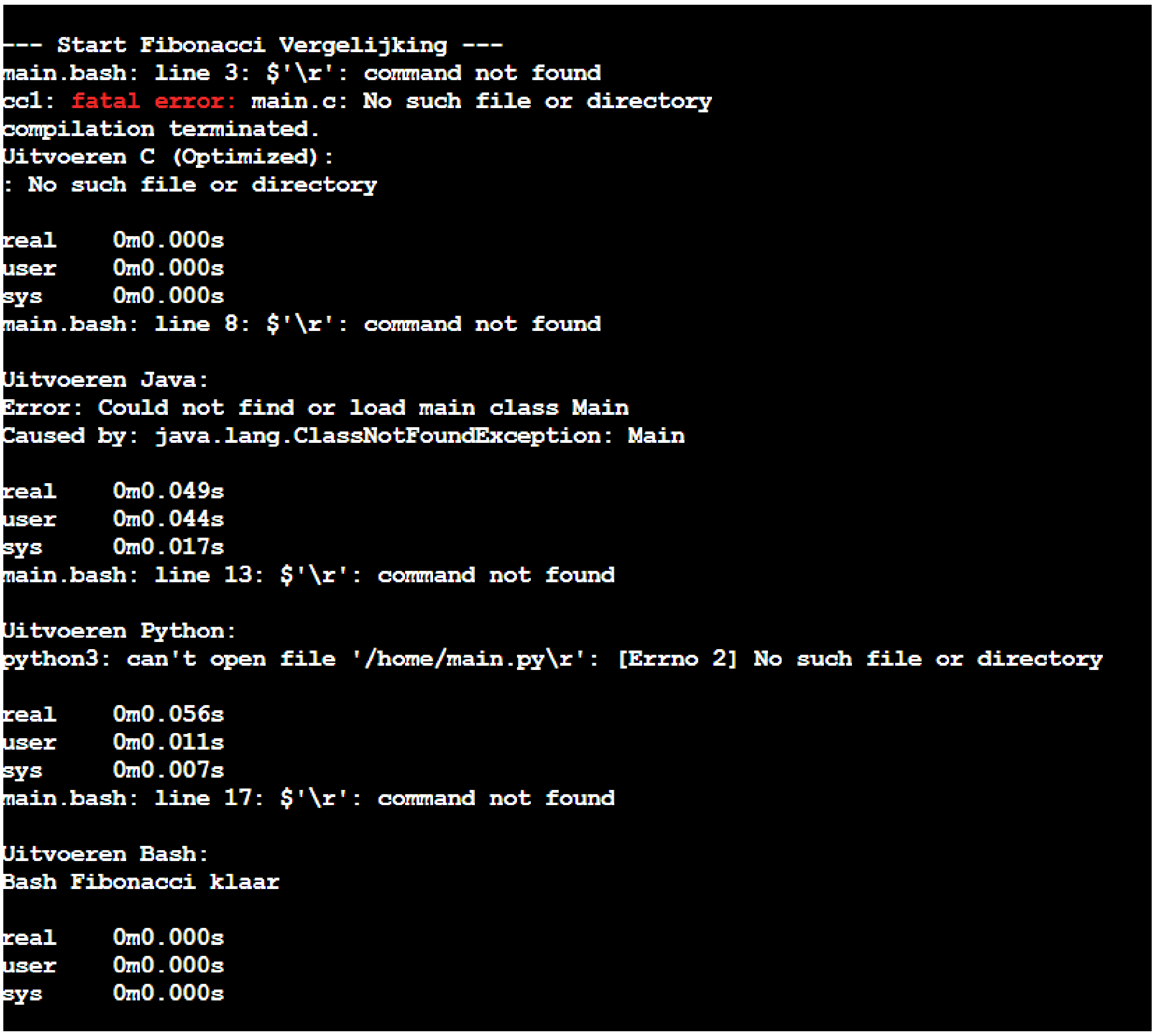
```
gcc -O3 main.c -o fib_optimized


...Program finished with exit code 0
Press ENTER to exit console.
```

c) Run the newly compiled program. Is it true that it now performs the calculation faster?

Yes it runs faster and the calculation also

d) Edit the file **runall.sh**, so you can perform all four calculations in a row using this Bash script. So the (compiled/interpreted) C, Java, Python and Bash versions of Fibonacci one after the other.

Volgorde van snelheid: 1. C (Machinecode) -> 2. Java (Bytecode) -> 3. Python/Bash (Interpreted).



```
--- Start Fibonacci Vergelijking ---
main.bash: line 3: $'\r': command not found
cc1: fatal error: main.c: No such file or directory
compilation terminated.
Uitvoeren C (Optimized):
: No such file or directory

real    0m0.000s
user    0m0.000s
sys     0m0.000s
main.bash: line 8: $'\r': command not found

Uitvoeren Java:
Error: Could not find or load main class Main
Caused by: java.lang.ClassNotFoundException: Main

real    0m0.049s
user    0m0.044s
sys     0m0.017s
main.bash: line 13: $'\r': command not found

Uitvoeren Python:
python3: can't open file '/home/main.py\r': [Errno 2] No such file or directory

real    0m0.056s
user    0m0.011s
sys     0m0.007s
main.bash: line 17: $'\r': command not found

Uitvoeren Bash:
Bash Fibonacci klaar

real    0m0.000s
user    0m0.000s
sys     0m0.000s
```

Kreeg deze niet volledig werkend begrijp het wel was wel heel ver gekomen

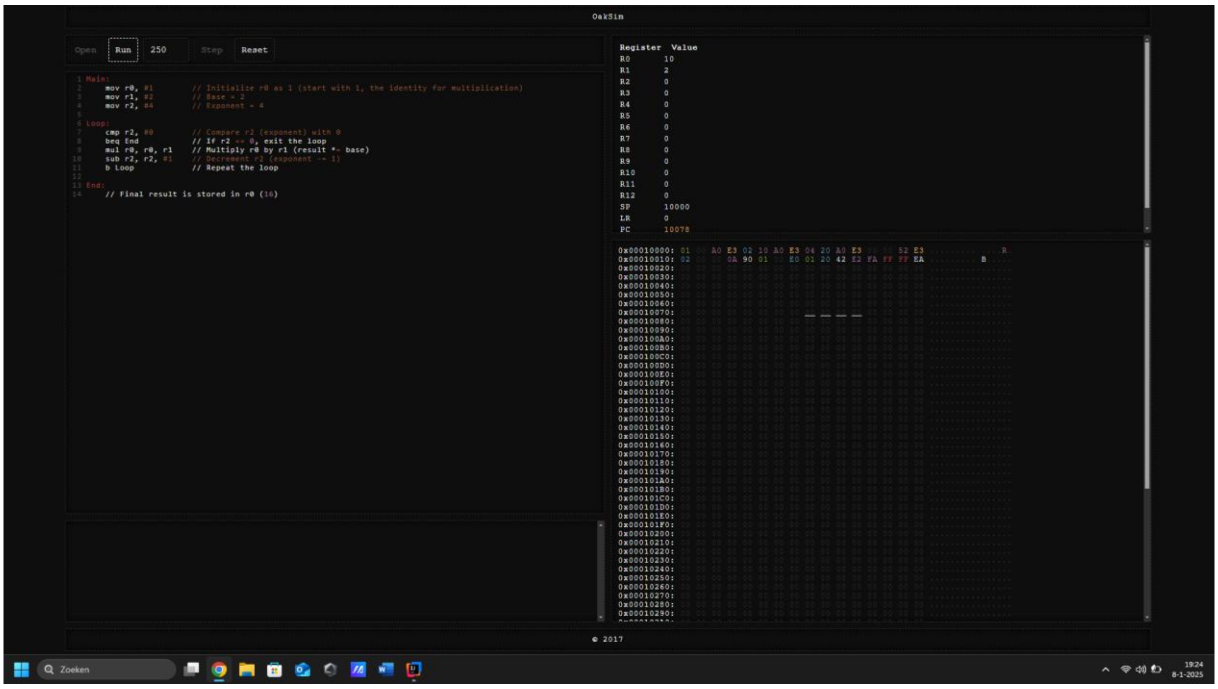
Assignment 4.5: More ARM Assembly

Like the factorial example, you can also implement the calculation of a power of 2 in assembly. For example you want to calculate $2^4 = 16$. Use iteration to calculate the result. Store the result in r0.

Complete the code. See the PowerPoint slides of week 4.

```
Main:

   mov r0, #1       // Initialize r0 as 1 (start with 1, the identity for multiplication)

   mov r1, #2       // Base = 2

   mov r2, #4       // Exponent = 4


Loop:

   cmp r2, #0       // Compare r2 (exponent) with 0

   beq End          // If r2 == 0, exit the loop

   mul r0, r0, r1   // Multiply r0 by r1 (result *= base)

   sub r2, r2, #1   // Decrement r2 (exponent -= 1)

   b Loop           // Repeat the loop


End:

   // Result  in r0
```

Screenshot of the completed code here.



```
Main:
    mov r0, #1        // Initialize r0 as 1 (start with 1, the identity for multiplication)
    mov r1, #2        // Base = 2
    mov r2, #4        // Exponent = 4

Loop:
    cmp r2, #0        // Compare r2 (exponent) with 0
    beq End           // If r2 == 0, exit the loop
    mul r0, r0, r1    // Multiply r0 by r1 (result *= base)
    sub r2, r2, #1    // Decrement r2 (exponent -= 1)
    b Loop            // Repeat the loop

End:
    // Final result is stored in r0 (16)
```

```
Register  Value
R0        10
R1        2
R2        0
R3        0
R4        0
R5        0
R6        0
R7        0
R8        0
R9        0
R10       0
R11       0
R12       0
SP        10000
LR        0
PC        10078
```

```
0x00010000: 01 00 A0 E3 02 10 A0 E3 04 20 A0 E3 00 00 52 E3 ..............R.
0x00010010: 02 00 00 0A 90 01 00 E0 01 20 42 E2 FA FF FF EA ............B...
0x00010020: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010030: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010040: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010050: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010060: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010070: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010080: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010090: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x000100A0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x000100B0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x000100C0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x000100D0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x000100E0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x000100F0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010100: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010110: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010120: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010130: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010140: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010150: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010160: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010170: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010180: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010190: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x000101A0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x000101B0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x000101C0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x000101D0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x000101E0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x000101F0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010200: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010210: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010220: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010230: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010240: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010250: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010260: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010270: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010280: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0x00010290: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
```

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