



FIRST EDITION – CHAPTER 8 REV 1

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Forward

This book is not associated or endorsed by the Rust Foundation. This is purely a FREE educational resource going step-by-step on how to build and reverse engineer Rust binaries.

Rust redefines how a binary is compiled. It does not operate with similar patterns like we see in older languages and is simply the most difficult language to reverse engineer in history.

Many of the C-style decompilers within the popular reversing tools are literally rendered useless with Rust.

Malware Authors are going the route of Rust as there are few tools that exist yet to properly statically analyze the compiled binaries which coupled with its speed and memory safety, it is very difficult to understand what it is actually doing.

The aim of this book is to teach basic Rust and step-by-step reverse engineer each simple binary to understand what is going on under the hood.

We will develop within the Windows architecture (Intel x64 CISC) as most malware targets this platform by orders of magnitude.

Let's begin...

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Chapter 1: Hello Rust

We begin our journey with developing a simple hello world program in Rust on a Windows 64-bit OS.

We will then reverse engineer the binary in IDA Free.

Let's first download Rust for Windows.

<https://www.rust-lang.org/tools/install>

Let's download IDA Free.

<https://hex-rays.com/ida-free/#download>

Let's download Visual Studio Code which we will use as our integrated development environment.

<https://code.visualstudio.com/>

Once installed, let's add the Rust extension within VS Code.

<https://marketplace.visualstudio.com/items?itemName=rust-lang.rust-analyzer>

It is important to update Rust so I would encourage you to run this before every project.

```
rustup update
```

Let's create a new project and get started by following the below steps.

```
cargo new one_hello
```

Now let's populate our **main.rs** file with the following.

```
fn main() {  
    println!("Hello, world!");  
}
```

Let's open up the terminal by click CTRL+SHIFT+` and type the following.

```
cargo build
```

Let's run the binary!

```
.\target\debug\one_hello.exe
```

Output...

Hello, world!

Congratulations! You just created your first hello world code in Rust. Time for cake!

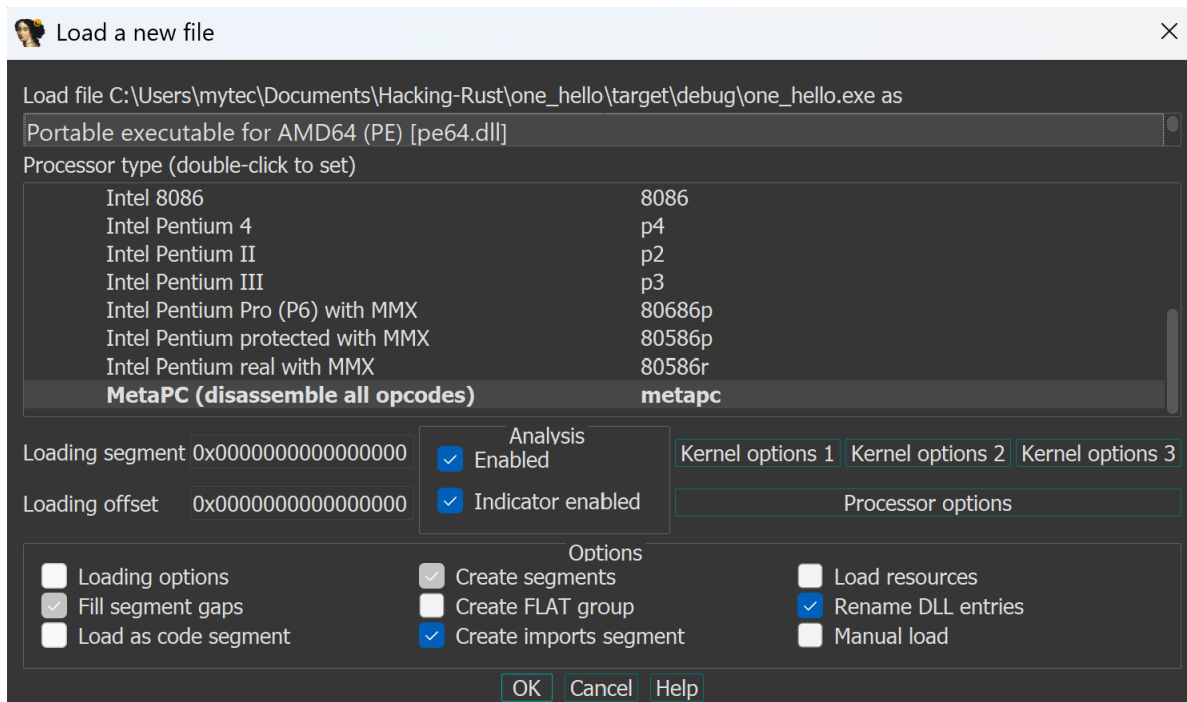
We simply created a hello world style example to get us started.

In our next lesson we will debug this in IDA Free!

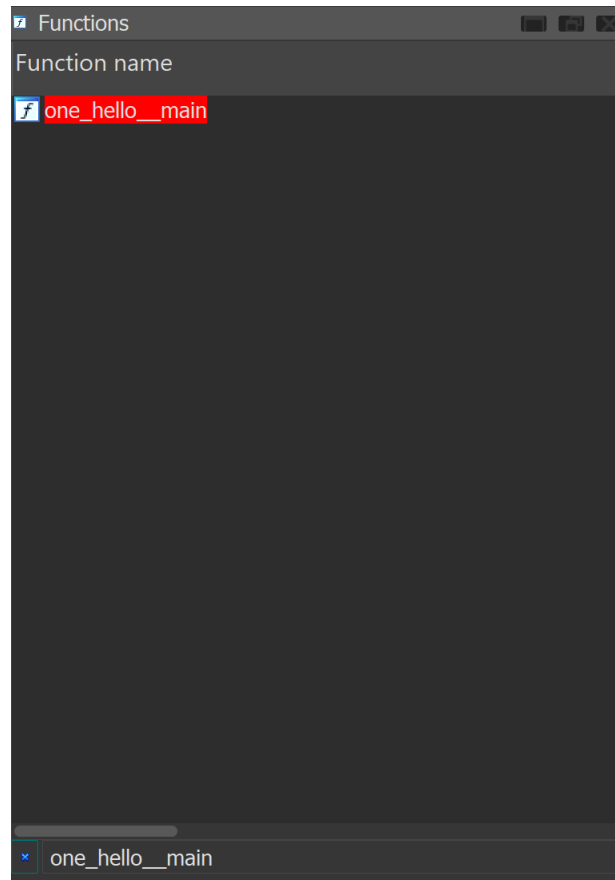
Chapter 2: Debugging Hello Rust

Let's debug our app within IDA Free.

Open IDA Free and we see the load screen. We can keep all the defaults and simply click OK.



In Rust at the assembler level we will need to search for the entry point of our app. This is the `one_hello__main` function. You can use CTRL+F to search.



Now we can double-click on the `one_hello__main` to launch the focus to this function and graph.

```

; void __fastcall one_hello::main()
one_hello__main proc near

var_38= qword ptr -38h
var_30= byte ptr -30h

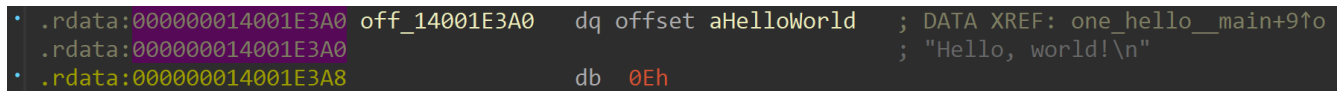
sub     rsp, 58h
lea     rcx, [rsp+58h+var_30]
lea     rdx, off_14001E3A0 ; "Hello, world!\n"
mov     r8d, 1
lea     r9, aInvalidArgs ; "invalid args"
xor     eax, eax
mov     [rsp+58h+var_38], 0
call    _ZN4core3fmt9Arguments6new_v117ha9b71491ca997d8aE ; core::fmt::Arguments::new_v1:ha9b71491ca997d8a
lea     rcx, [rsp+58h+var_30]
call    _ZN3std2io5stdio6_print17hce7a376ab49946d5E ; std::io::stdio::_print:hce7a376ab49946d5
nop
add     rsp, 58h
retn
one_hello__main endp

```

We can see in the terminal our *"Hello, world!\n"* text.



If we double-click on *off_14001E3A0* it will take us to a new window where the string lives within the binary.



Similar to Go, we can see the strings are in a string pool however we do see a `0Ah, 0` so it contains the newline and null terminator as Go handles it slightly different.

These lessons are designed to be short and digestible so that you can code and hack along.

In our next lesson we will learn how to hack this string and force the binary to print something else to the terminal of our choosing.

This will give us the first taste on hacking Rust!

Chapter 3: Hacking Hello Rust

Let's hack our app with IDA Free.

Let's load up IDA and revisit the binary.



```
; void __fastcall one_hello::main()
one_hello__main proc near

var_38= qword ptr -38h
var_30= byte ptr -30h

sub     rsp, 58h
lea     rcx, [rsp+58h+var_30]
lea     rdx, off_14001E3A0 ; "Hello, world!\n"
mov     r8d, 1
lea     r9, aInvalidArgs ; "invalid args"
xor     eax, eax
mov     [rsp+58h+var_38], 0
call    _ZN4core3fmt9Arguments6new_v117ha9b71491ca997d8aE ; core::fmt::Arguments::new_v1::ha9b71491ca997d8a
lea     rcx, [rsp+58h+var_30]
call    _ZN3std2io5stdio6_print17hce7a376ab49946d5E ; std::io::stdio::_print::hce7a376ab49946d5
nop
add     rsp, 58h
retn
one_hello__main endp
```

We start off with subtracting `0x58` bytes from `RSP`. We do not see the C-style prologue here. What we are seeing is what the Rust compiler chose to do at compile time.

This is a VERY simple example but I want to take the time to step through this step-by-step.

Let's set a breakpoint at the entry.

```

; void __fastcall one_hello::main()
one_hello__main proc near

var_38= qword ptr -38h
var_30= byte ptr -30h

sub     rsp, 58h
lea     rcx, [rsp+58h+var_30]
lea     rdx, off_14001E3A0 ; "Hello, world!\n"
mov     r8d, 1
lea     r9, aInvalidArgs ; "invalid args"
xor     eax, eax
mov     [rsp+58h+var_38], 0
call    _ZN4core3fmt9Arguments6new_v117ha9b71491ca997d8aE ; core::fmt::Arguments::new_v1::ha9b71491ca997d8a
lea     rcx, [rsp+58h+var_30]
call    _ZN3std2io5stdio6_print17hce7a376ab49946d5E ; std::io::stdio::_print::hce7a376ab49946d5
nop
add     rsp, 58h
retn
one_hello__main endp

```

Lets run.

The screenshot shows a debugger window with assembly code on the left and system information on the right. The assembly code is the same as in the first block, with addresses ranging from 00007FF6EE761080 to 00007FF6EE7610BC. The right pane shows the 'General registers' section with the following values:

Register	Value	ID	VIP	VIF	AC	VM	RF	NT
RSI	0000006435D3FB80	0						
RDI	0000006435D3FB50	0						
RBP	0000006435D3FB50	0						
RSP	0000006435D3FA18	0						
RIP	00007FF6EE761080	0						
R8	00000217817B8030	0						

The 'Modules' section shows the following loaded modules:

Path	Base
C:\Users\mytec\Documents\Hacking-Rust\one_hello\target\debug\one_hello.exe	00007FF6EE760000
C:\WINDOWS\SYSTEM32\VCRUNTIME140.dll	00007FFC53350000
C:\WINDOWS\System32\userbase.dll	00007FFC5A370000
C:\WINDOWS\System32\USER32.dll	00007FFC5A7F0000

The 'Threads' section shows the following threads:

Decimal	Hex	State	Name
32532	7F14	Ready	main
20228	4F04	Ready	7FFC5CD45430
31624	7B88	Ready	7FFC5CD45430

Lets take note where *RSP* is *0x0000006435d3fa18*.

Lets step once.

```

.text:00007FF6EE761080 var_38= qword ptr -38h
.text:00007FF6EE761080 var_30= byte ptr -30h
.text:00007FF6EE761080
.text:00007FF6EE761080 sub     rsp, 58h
.text:00007FF6EE761080 lea     rcx, [rsp+58h+var_30]
.text:00007FF6EE761080 lea     rdx, off_7FF6EE77E3A0 ; "Hello, world!\n"
.text:00007FF6EE761080 mov     r8d, 1
.text:00007FF6EE761080 lea     r9, aInvalidArgs ; "Invalid args"
.text:00007FF6EE761080 xor     eax, eax
.text:00007FF6EE761080 mov     [rsp+58h+var_38], 0
.text:00007FF6EE761080 call    _ZN4core3fmt9Arguments6new_v117ha9b71491ca997d8aE ; core::fmt::Argument
.text:00007FF6EE761080 lea     rcx, [rsp+58h+var_30]
.text:00007FF6EE761080 call    _ZN3std2io5Stdio6_print17hce7a376ab49946d5E ; std::io::stdio::print
.text:00007FF6EE761080 nop
.text:00007FF6EE761080 add     rsp, 58h
.text:00007FF6EE761080 retn
.text:00007FF6EE761080 one_hello_main_endp

```

We now see the value of *RSP* at *0x0000006435df9c0*. This makes sense as *0x0000006435d3fa18 - 0x58 = 0x0000006435d3f9c0*.

Next we see *lea rcx, [rsp+58h+var_30]* so let's break this down.

LEA stands for "Load Effective Address." It is a versatile instruction that can be used to perform arithmetic calculations on addresses without actually accessing memory.

RCX is the destination register where the effective address will be stored.

[rsp+58h+var_30] is the source operand, representing the address that needs to be calculated. It consists of multiple parts:

- * *RSP* is the stack pointer register.
- * *58h* is a hexadecimal constant value, which represents an offset from the stack pointer.
- * *var_30* refers to a variable or memory location. In this case, it is *-30h*, indicating a byte-sized variable or memory location located at an offset of *-30h* (or *-48* in decimal) from the stack pointer.

Therefore, *lea rcx, [rsp+58h+var_30]* calculates the effective address by adding the stack pointer (*RSP*) with an offset of *58h* and the variable *var_30* located at an offset of *-30h* from the stack pointer. The resulting effective address is stored in the *RCX* register.

Next we see an offset value being loaded into *RDX*.

```

.text:00007FF6EE761080
.text:00007FF6EE761080
.text:00007FF6EE761080
.text:00007FF6EE761080 ; void __fastcall one_hello::main()
.text:00007FF6EE761080 one_hello__main proc near
.text:00007FF6EE761080
.text:00007FF6EE761080 var_38= qword ptr -38h
.text:00007FF6EE761080 var_30= byte ptr -30h
.text:00007FF6EE761080
.text:00007FF6EE761080 sub     rsp, 58h
.text:00007FF6EE761084 lea     rcx, [rsp+58h+var_30]
.text:00007FF6EE761089 lea     rdx, off_7FF6EE77E3A0 ; "Hello, world!\n"
.text:00007FF6EE761090 mov     r8d, 1
.text:00007FF6EE761096 lea     r9, aInvalidArgs ; "invalid args"
.text:00007FF6EE76109D xor     eax, eax
.text:00007FF6EE76109F mov     [rsp+58h+var_38], 0
.text:00007FF6EE7610A8 call    _ZN4core3fmt9Arguments6new_v117ha9b71491ca997d8aE ; core::fmt::Argu
.text:00007FF6EE7610AD lea     rcx, [rsp+58h+var_30]
.text:00007FF6EE7610B2 call    _ZN3std2io5stdio6_print17hce7a376ab49946d5E ; std::io::stdio::_prin
.text:00007FF6EE7610B7 nop
.text:00007FF6EE7610B8 add     rsp, 58h
.text:00007FF6EE7610BC retn
.text:00007FF6EE7610BC one_hello__main endp

```

This is our string. Let's double-click on the offset.

```

.rdata:00007FF6EE77E3A0 off_7FF6EE77E3A0 dq offset aHelloWorld ; DATA XREF: one_hello__main+9f0
.rdata:00007FF6EE77E3A0 ; "Hello, world!\n"
.rdata:00007FF6EE77E3A8 db 0Eh


```

We see 13 chars and the null terminator therefore 0x0e.

Let's stop the debug and click on the "Hello, world!\n" text and view the *Hex View-1*.



```
00007FF6EE77E390 48 65 6C 6C 6F 2C 20 77 6F 72 6C 64 21 0A 00 00 Hello,.world!...
00007FF6EE77E3A0 90 E3 77 EE F6 7F 00 00 0E 00 00 00 00 00 00 00 .....
```



Patch Bytes

Address: 0x7FF6EE77E390

File offset: 0x1D390

Original value: 48 65 6C 6C 6F 2C 20 77 6F 72 6C 64 21 0A 00 00

Values: 48 65 6C 6C 6F 2C 20 77 6F 72 6C 64 21 0A 00 00

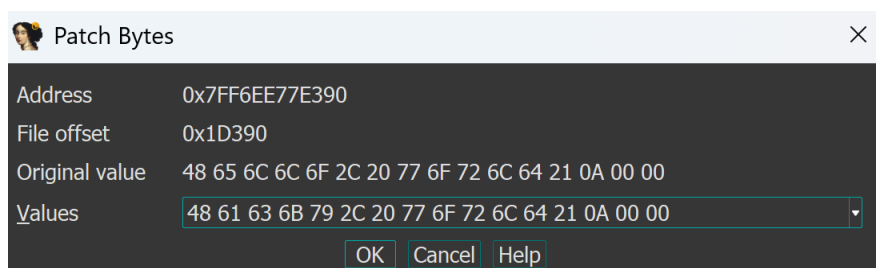
OK Cancel Help

13

```

'H' -> 0x48
'a' -> 0x61
'c' -> 0x63
'k' -> 0x6B
'y' -> 0x79
', ' -> 0x2C
' ' -> 0x20
'w' -> 0x77
'o' -> 0x6F
'r' -> 0x72
'l' -> 0x6C
'd' -> 0x64
'!' -> 0x21

```



Click OK.

```

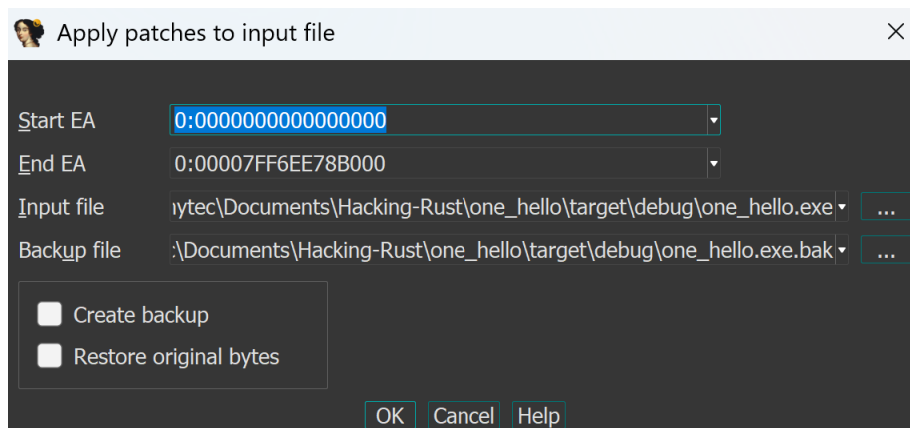
00007FF6EE77E390 48 61 63 6B 79 2C 20 77 6F 72 6C 64 21 0A 00 00 Hacky, world!...
00007FF6EE77E3A0 90 E3 77 EE F6 7F 00 00 0E 00 00 00 00 00 00 00 .....

```

SUCCESS!

Press the red stop button to stop debugging.

Click edit – Patch program – Apply patches to input file...



Let's run again...

```
.text:00007FF628C21080 var_38= qword ptr -38h
.text:00007FF628C21080 var_30= byte ptr -30h
.text:00007FF628C21080
RCX RIP ✓.text:00007FF628C21080 sub    rsp, 58h
.text:00007FF628C21084 lea     rcx, [rsp+58h+var_30]
.text:00007FF628C21089 lea     rdx, off_7FF628C3E3A0 ; "Hacky, world!\n"
.text:00007FF628C21090 mov     r8d, 1
.text:00007FF628C21096 lea     r9, aInvalidArgs ; "invalid args"
.text:00007FF628C2109D xor     eax, eax
.text:00007FF628C2109F mov     [rsp+58h+var_38], 0
.text:00007FF628C210A8 call    _ZN4core3fmt9Arguments6new_v117ha9b71491ca997d8aE ; core::fmt::Arguments::new_v1::ha9b71491ca997d8a
.text:00007FF628C210AD lea     rcx, [rsp+58h+var_30]
.text:00007FF628C210B2 call    _ZN3std2io5stdio6_print17hce7a376ab49946d5E ; std::io::stdio::_print::hce7a376ab49946d5
.text:00007FF628C210B7 nop
.text:00007FF628C210B8 add     rsp, 58h
.text:00007FF628C210BC retn
.text:00007FF628C210BC one_hello__main endp
```

Let's F8, step over, until the *NOP*.

Observe the command window.

```
C:\Users\mytec\Documents\> Hacky, world!
```

SUCCESS! We have successfully hacked our first Rust binary!

The rest of the Assembler is trivial as we are just calling `std::io::stdio::_print` to echo the line to `STDOUT`.

Stay tuned as this will get significantly more challenging. With all things we start small and build!

In our next chapter we will discuss the Scalar Data Types.

Chapter 4: Scalar Data Types

We continue our journey with a scalar data types example program in Rust on a Windows 64-bit OS.

Let's create a new project and get started by following the below steps.

```
cargo new two_scalar-data-types
```

Now let's populate our **main.rs** file with the following.

```
fn main() {  
    let my_integer: i32 = 42;  
    println!("integer: {}", my_integer);  
  
    let my_float: f64 = 3.14;  
    println!("float: {}", my_float);  
  
    let my_char: char = 'A';  
    println!("character: {}", my_char);  
}
```

Let's open up the terminal by click CTRL+SHIFT+` and type the following.

```
cargo build
```

Let's run the binary!

```
.\target\debug\two_scalar-data-types.exe
```

Output...

```
integer: 42  
float: 3.14  
character: A
```

Congratulations! You just created another program in Rust. Time for cake!

We simply created an example of each of the scalar data types which are int, float and char.

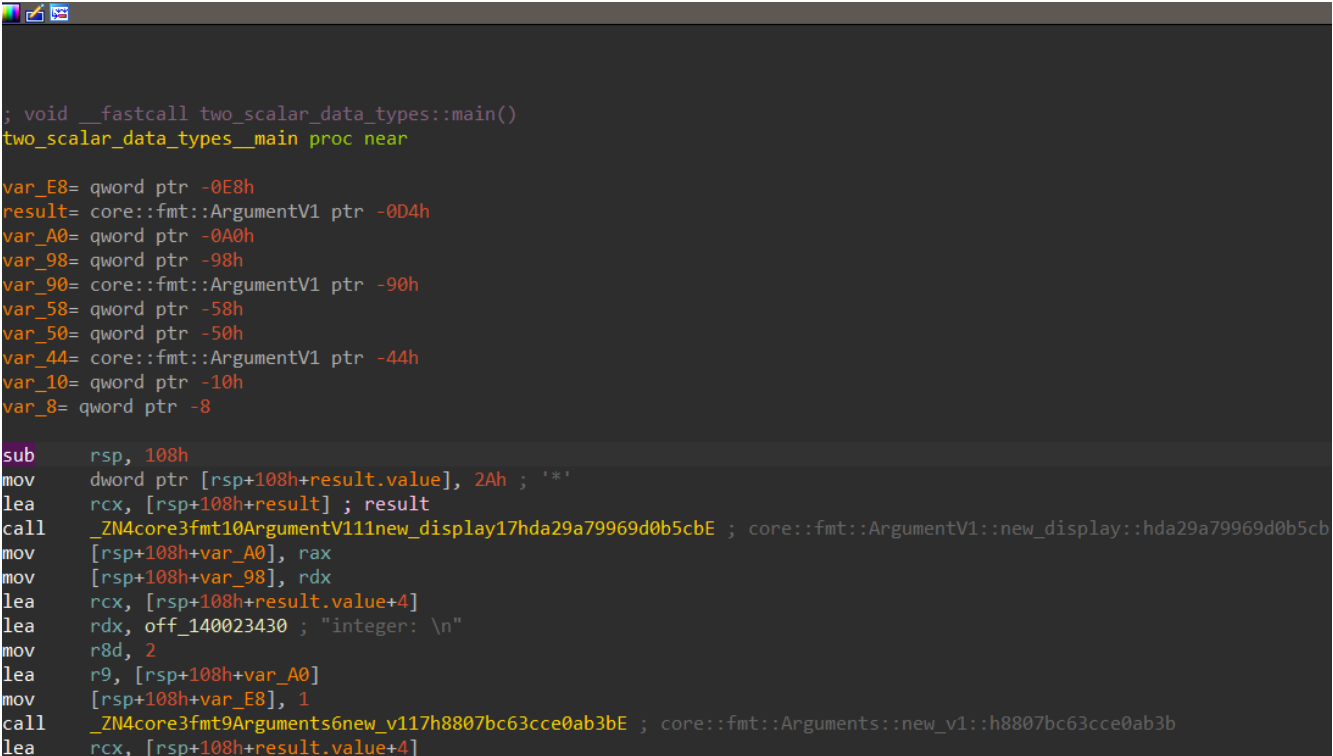
In our next lesson we will debug this in IDA Free!

Chapter 5: Debugging Scalar Data Types

Let's debug our app within IDA Free.

Open IDA Free and we see the load screen. We can keep all the defaults and simply click OK.

On the left-hand side we see the Function name window and we want to search for `two_scalar_data_types__main`. Double-click it and we will see the function.



```
; void __fastcall two_scalar_data_types::main()
two_scalar_data_types__main proc near

var_E8= qword ptr -0E8h
result= core::fmt::ArgumentV1 ptr -0D4h
var_A0= qword ptr -0A0h
var_98= qword ptr -98h
var_90= core::fmt::ArgumentV1 ptr -90h
var_58= qword ptr -58h
var_50= qword ptr -50h
var_44= core::fmt::ArgumentV1 ptr -44h
var_10= qword ptr -10h
var_8= qword ptr -8

sub     rsp, 108h
mov     dword ptr [rsp+108h+result.value], 2Ah ; '*'
lea     rcx, [rsp+108h+result] ; result
call    _ZN4core3fmt10ArgumentV111new_display17hda29a79969d0b5cbE ; core::fmt::ArgumentV1::new_display::hda29a79969d0b5cb
mov     [rsp+108h+var_A0], rax
mov     [rsp+108h+var_98], rdx
lea     rcx, [rsp+108h+result.value+4]
lea     rdx, off_140023430 ; "integer: \n"
mov     r8d, 2
lea     r9, [rsp+108h+var_A0]
mov     [rsp+108h+var_E8], 1
call    _ZN4core3fmt9Arguments6new_v117h8807bc63cce0ab3bE ; core::fmt::Arguments::new_v1::h8807bc63cce0ab3b
lea     rcx, [rsp+108h+result.value+4]
```

```

call    _ZN4core3fmt10ArgumentV111new_display17h0ac0f3d1bf4c49e3E ; core::fmt::ArgumentV1::new_display:h0ac0f3d1bf4c49e3
mov     [rsp+108h+var_58], rax
mov     [rsp+108h+var_50], rdx
lea     rcx, [rsp+108h+var_90.formatter]
lea     rdx, off_140023458 ; "float: "
mov     r8d, 2
lea     r9, [rsp+108h+var_58]
mov     [rsp+108h+var_E8], 1
call    _ZN4core3fmt9Arguments6new_v117h8807bc63cce0ab3bE ; core::fmt::Arguments::new_v1:h8807bc63cce0ab3b
lea     rcx, [rsp+108h+var_90.formatter]
call    _ZN3std2io5stdio6_print17hce7a376ab49946d5E ; std::io::stdio::_print:hce7a376ab49946d5
mov     dword ptr [rsp+108h+var_44.value], 41h ; 'A'
lea     rcx, [rsp+108h+var_44] ; result
call    _ZN4core3fmt10ArgumentV111new_display17h2cdf30f7c1587727E ; core::fmt::ArgumentV1::new_display:h2cdf30f7c1587727
mov     [rsp+108h+var_10], rax
mov     [rsp+108h+var_8], rdx
lea     rcx, [rsp+108h+var_44.value+4]
lea     rdx, off_140023488 ; "character: "
mov     r8d, 2
lea     r9, [rsp+108h+var_10]
mov     [rsp+108h+var_E8], 1
call    _ZN4core3fmt9Arguments6new_v117h8807bc63cce0ab3bE ; core::fmt::Arguments::new_v1:h8807bc63cce0ab3b
lea     rcx, [rsp+108h+var_44.value+4]
call    _ZN3std2io5stdio6_print17hce7a376ab49946d5E ; std::io::stdio::_print:hce7a376ab49946d5
nop
add     rsp, 108h
retn
two_scalar_data_types__main endp

```

We see the below instruction.

```
mov     dword ptr [rsp+108h+result.value], 2Ah ; '*'
```

The value of 2Ah is 42 so we know that the literal value is being stored inside RSP + the offset value above.

We then see a call to the **println!** macro.

```
call    _ZN3std2io5stdio6_print17hce7a376ab49946d5E ; std::io::stdio::_print:hce7a376ab49946d5
```

Bare with me as I explain the floating point number. Let's first review the actual code we are going to statically reverse.

```
let my_float: f64 = 3.14;
println!("float: {}", my_float);
```

The first instruction loads the floating-point value 3.14 from memory into the XMM0 register. The XMM registers are 128-bit registers that are used to store floating-point values and vectors.

```
movsd   xmm0, cs: real@40091eb851eb851f
```

The next instruction stores the value in XMM0 to the memory location `rsp+108h+var_90.value`. This memory location is part of the stack frame that is allocated for the `println!` macro call.

```
movsd [rsp+108h+var_90.value], xmm0
```

The next instruction sets the register `rcx` to point to the memory location `rsp+108h+var_90`. This memory location contains the `ArgumentV1` struct that will be passed to the `new_display` function.

```
lea rcx, [rsp+108h+var_90] ; result
```

The next instruction calls the `new_display` function. The `new_display` function is responsible for converting the `ArgumentV1` struct into a string representation.

```
call _ZN4core3fmt10ArgumentV111new_display17h0ac0f3d1bf4c49e3E ; core::fmt::ArgumentV1::new_display:h0ac0f3d1bf4c49e3
```

The `new_display` function returns the string representation in the `RAX` and `RDX` registers. The next instruction stores the value in `RAX` to the memory location `rsp+108h+var_58`. This memory location contains the `Formatter` struct that will be passed to the `println!` macro.

```
mov [rsp+108h+var_58], rax
```

The next instruction stores the value in `RDX` to the memory location `rsp+108h+var_50`. This memory location contains the slice of bytes that represents the string representation of the `ArgumentV1` struct.

```
mov [rsp+108h+var_50], rdx
```

The next instruction sets the register `RCX` to point to the memory location `rsp+108h+var_90.formatter`. This memory location contains the `Formatter` struct that will be passed to the `println!` macro.

```
lea rcx, [rsp+108h+var_90.formatter]
```

The next instruction sets the register `RDX` to point to the string literal `"float: "`.

```
lea rdx, off_140023458 ; "float: "
```

Finally we see the `println!` macro print the value.

```
call _ZN3std2io5stdio6_print17hce7a376ab49946d5E ; std::io::stdio::print::hce7a376ab49946d5
```

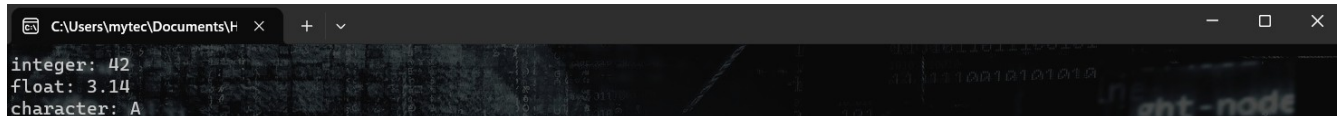
The last item was the char 'A' which is simply moved into RSP and an offset below.

```
mov     dword ptr [rsp+108h+var_44.value], 41h ; 'A'
```

Then we print.

```
call    _ZN3std2io5stdio6_print17hce7a376ab49946d5E ; std::io::stdio::_print::hce7a376ab49946d5
```

Below are the results in the terminal.



```
C:\Users\mytec\Documents\H  X + v
integer: 42
float: 3.14
character: A
```

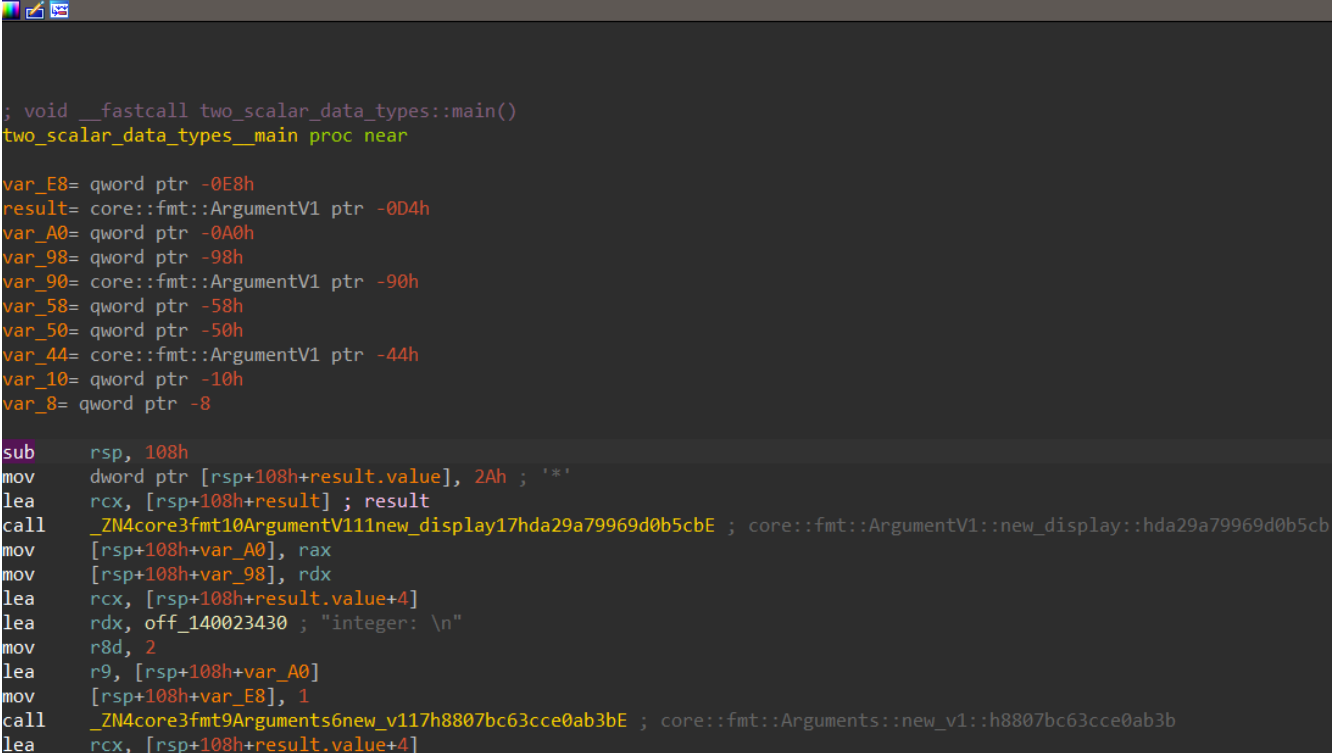
In our next lesson we will hack this!

Chapter 6: Hacking Scalar Data Types

Let's hack our app within IDA Free.

Open IDA Free and we see the load screen. We can keep all the defaults and simply click OK.

On the left-hand side we see the Function name window and we want to search for `two_scalar_data_types__main`. Double-click it and we will see the function.



```
; void __fastcall two_scalar_data_types::main()
two_scalar_data_types__main proc near

var_E8= qword ptr -0E8h
result= core::fmt::ArgumentV1 ptr -0D4h
var_A0= qword ptr -0A0h
var_98= qword ptr -98h
var_90= core::fmt::ArgumentV1 ptr -90h
var_58= qword ptr -58h
var_50= qword ptr -50h
var_44= core::fmt::ArgumentV1 ptr -44h
var_10= qword ptr -10h
var_8= qword ptr -8

sub     rsp, 108h
mov     dword ptr [rsp+108h+result.value], 2Ah ; '*'
lea     rcx, [rsp+108h+result] ; result
call    _ZN4core3fmt10ArgumentV111new_display17hda29a79969d0b5cbE ; core::fmt::ArgumentV1::new_display::hda29a79969d0b5cb
mov     [rsp+108h+var_A0], rax
mov     [rsp+108h+var_98], rdx
lea     rcx, [rsp+108h+result.value+4]
lea     rdx, off_140023430 ; "integer: \n"
mov     r8d, 2
lea     r9, [rsp+108h+var_A0]
mov     [rsp+108h+var_E8], 1
call    _ZN4core3fmt9Arguments6new_v117h8807bc63cce0ab3bE ; core::fmt::Arguments::new_v1::h8807bc63cce0ab3b
lea     rcx, [rsp+108h+result.value+4]
```

```

call    _ZN4core3fmt10ArgumentV111new_display17h0ac0f3d1bf4c49e3E ; core::fmt::ArgumentV1::new_display:h0ac0f3d1bf4c49e3
mov     [rsp+108h+var_58], rax
mov     [rsp+108h+var_50], rdx
lea     rcx, [rsp+108h+var_90.formatter]
lea     rdx, off_140023458 ; "float: "
mov     r8d, 2
lea     r9, [rsp+108h+var_58]
mov     [rsp+108h+var_E8], 1
call    _ZN4core3fmt9Arguments6new_v117h8807bc63cce0ab3bE ; core::fmt::Arguments::new_v1:h8807bc63cce0ab3b
lea     rcx, [rsp+108h+var_90.formatter]
call    _ZN3std2io5stdio6_print17hce7a376ab49946d5E ; std::io::stdio::_print:hce7a376ab49946d5
mov     dword ptr [rsp+108h+var_44.value], 41h ; 'A'
lea     rcx, [rsp+108h+var_44] ; result
call    _ZN4core3fmt10ArgumentV111new_display17h2cdf30f7c1587727E ; core::fmt::ArgumentV1::new_display:h2cdf30f7c1587727
mov     [rsp+108h+var_10], rax
mov     [rsp+108h+var_8], rdx
lea     rcx, [rsp+108h+var_44.value+4]
lea     rdx, off_140023488 ; "character: "
mov     r8d, 2
lea     r9, [rsp+108h+var_10]
mov     [rsp+108h+var_E8], 1
call    _ZN4core3fmt9Arguments6new_v117h8807bc63cce0ab3bE ; core::fmt::Arguments::new_v1:h8807bc63cce0ab3b
lea     rcx, [rsp+108h+var_44.value+4]
call    _ZN3std2io5stdio6_print17hce7a376ab49946d5E ; std::io::stdio::_print:hce7a376ab49946d5
nop
add     rsp, 108h
retn
two_scalar_data_types__main endp

```

We see the below instruction.

```
mov     dword ptr [rsp+108h+result.value], 2Ah ; '*'
```

The value of 2Ah is 42 so we know that the literal value is being stored inside RSP + the offset value above.

Let's set a breakpoint by highlighting the line and pressing F2.

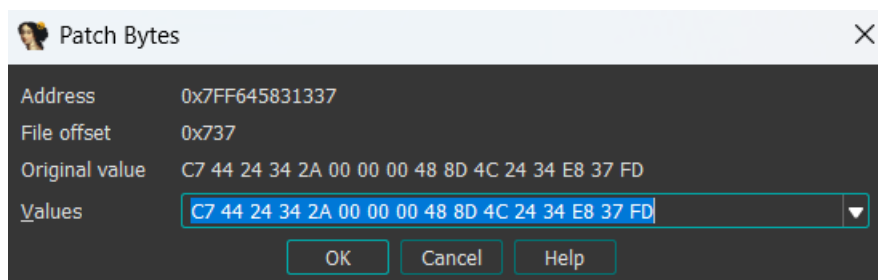
```
mov     dword ptr [rsp+108h+result.value], 2Ah ; '*'
```

Press play to debug.

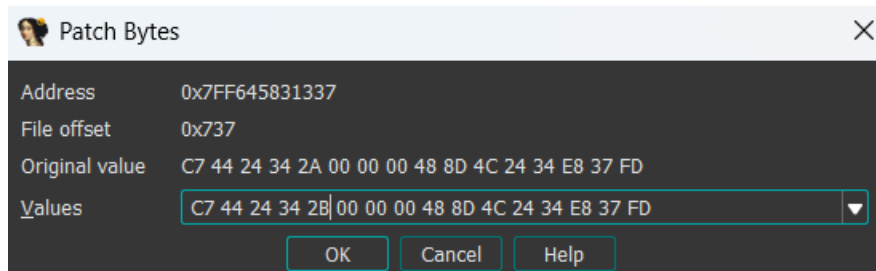
We now see the our breakpoint triggered.

```
.text:00007FF645831337 mov     dword ptr [rsp+108h+result.value], 2Ah
```

Click edit - Patch program - Change byte...



Change the 2A to 2B.



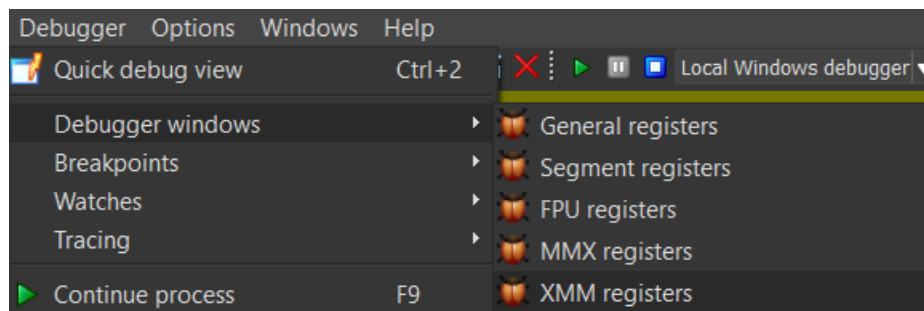
Click ok. We have now hacked our 42 value to 43!

Let's put a breakpoint on the below line.

```
.text:00007FF73743138A movsd [rsp+108h+var_90.value], xmm0
```

Lets press F9 to run to it.

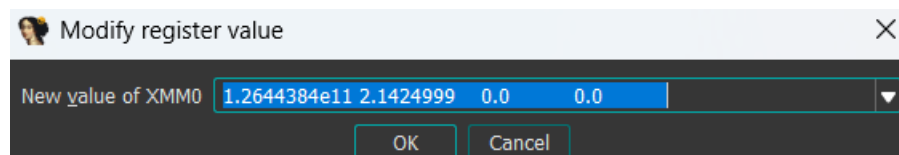
Click on Debugger – Debugger windows – XMM registers



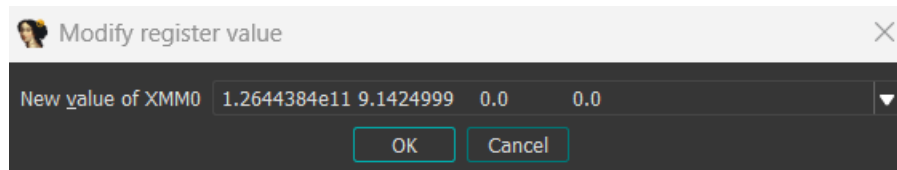
It will load the XMM registers.

```
XMM0 1.2644384e11 2.1424999 0.0 0.0
```

Double-click on the 2.1424999.



Change the value to 9 instead of 2.



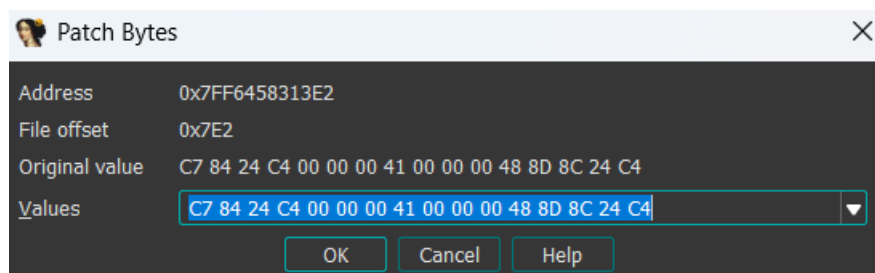
Press OK.

We have successfully hacked 3.14 to 299499.58!

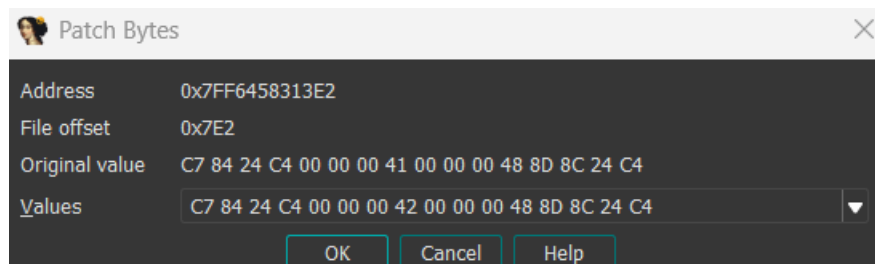
Put a breakpoint on the below line and press F9.

```
.text:00007FF6458313E2 mov     dword ptr [rsp+108h+var_44.value], 41h
```

Click edit - Patch program - Change byte...



Change 41 to 42.



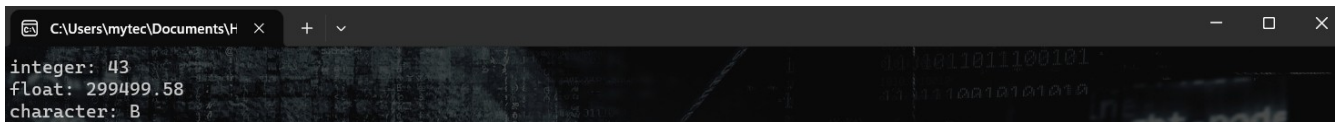
Press the red stop button to stop debugging.

Click edit - Patch program - Apply patches to input file...

Place a breakpoint on the NOP under the final call to *println!* macro.

```
call     _ZN3std2io5stdio6_print17hce7a376ab49946d5E ; std::io::stdio::_print::hce7a376ab49946d5
nop
```


BOOM!

A screenshot of a terminal window with a dark background and a grid pattern. The window title bar shows the file path 'C:\Users\mytec\Documents\h' and standard window controls. The terminal displays the following text: 'integer: 43', 'float: 299499.58', and 'character: B'. In the background, there are faint binary strings like '111011011100101' and '1111110010101010'.

In our next lesson we will handle Compound Data Types.

Chapter 7: Compound Data Types

We continue our journey with a compound data types example program in Rust on a Windows 64-bit OS.

Let's create a new project and get started by following the below steps.

```
cargo new three_compound-data-types
```

Now let's populate our **main.rs** file with the following.

```
fn main() {  
    let tup = (1337, 3.14, 42);  
    let (x, y, z) = tup;  
    println!("x: {x}");  
    println!("y: {y}");  
    println!("z: {z}");  
  
    let x = [1, 2, 3];  
    let one = x[0];  
    let two = x[1];  
    let three = x[2];  
    println!("one: {one}");  
    println!("two: {two}");  
    println!("three: {three}");  
}
```

Let's open up the terminal by click CTRL+SHIFT+` and type the following.

```
cargo build
```

Let's run the binary!

```
.\target\debug\three_compound-data-types.exe
```

Output...

```
x: 1337  
y: 3.14  
z: 42  
one: 1  
two: 2  
three: 3
```

Congratulations! You just created another program in Rust. Time for cake!

We simply created an example of each of the compound data types which are tuple and array.

In our next lesson we will debug this in IDA Free!

Chapter 8: Debugging Scalar Data Types

Let's debug our app within IDA Free.

Open IDA Free and we see the load screen. We can keep all the defaults and simply click OK.

On the left-hand side we see the Function name window and we want to search for *three_compound_data_types__main*. Double-click it and we will see the function.

```
; void __fastcall three_compound_data_types::main()  
three_compound_data_types__main proc near
```

```
var_2C8= qword ptr -2C8h  
var_2B8= qword ptr -2B8h  
var_2B0= qword ptr -2B0h  
var_2A8= qword ptr -2A8h  
var_2A0= qword ptr -2A0h  
var_298= qword ptr -298h  
var_290= qword ptr -290h  
var_288= qword ptr -288h  
var_280= qword ptr -280h  
var_278= dword ptr -278h  
var_274= dword ptr -274h  
var_26C= dword ptr -26Ch  
var_268= qword ptr -268h  
var_25C= dword ptr -25Ch  
var_258= byte ptr -258h  
var_228= qword ptr -228h  
var_220= qword ptr -220h  
var_218= byte ptr -218h  
var_1E8= qword ptr -1E8h  
var_1E0= qword ptr -1E0h  
var_1D8= byte ptr -1D8h  
var_1A8= qword ptr -1A8h  
var_1A0= qword ptr -1A0h  
var_198= dword ptr -198h  
var_194= dword ptr -194h
```

```
var_194= dword ptr -194h  
var_190= dword ptr -190h  
var_18C= dword ptr -18Ch  
var_188= dword ptr -188h  
var_184= dword ptr -184h  
var_180= byte ptr -180h  
var_150= qword ptr -150h  
var_148= qword ptr -148h  
var_140= byte ptr -140h  
var_110= qword ptr -110h  
var_108= qword ptr -108h  
var_100= byte ptr -100h  
var_D0= qword ptr -0D0h  
var_C8= qword ptr -0C8h  
var_C0= qword ptr -0C0h  
var_B8= qword ptr -0B8h  
var_B0= qword ptr -0B0h  
var_A8= qword ptr -0A8h  
var_A0= qword ptr -0A0h  
var_98= qword ptr -98h  
var_90= qword ptr -90h  
var_88= qword ptr -88h  
var_80= qword ptr -80h  
var_78= qword ptr -78h  
var_70= qword ptr -70h  
var_68= qword ptr -68h  
var_60= qword ptr -60h  
var_58= qword ptr -58h  
var_50= qword ptr -50h  
var_48= qword ptr -48h  
var_40= qword ptr -40h  
var_38= qword ptr -38h
```

```

var_38= qword ptr -38h
var_30= qword ptr -30h
var_28= qword ptr -28h
var_20= qword ptr -20h
var_18= qword ptr -18h
var_10= qword ptr -10h
var_8= qword ptr -8

sub     rsp, 2E8h
mov     [rsp+2E8h+var_278], 539h
mov     rax, 40091EB851EB851Fh
mov     [rsp+2E8h+var_280], rax
mov     [rsp+2E8h+var_274], 2Ah ; '*'
mov     eax, [rsp+2E8h+var_278]
mov     [rsp+2E8h+var_26C], eax
movsdb [rsp+2E8h+var_280], xmm0
movsdb [rsp+2E8h+var_268], xmm0
mov     eax, [rsp+2E8h+var_274]
mov     [rsp+2E8h+var_25C], eax
lea     rcx, [rsp+2E8h+var_26C]
mov     [rsp+2E8h+var_30], rcx
lea     rax, _ZN4core3fmt3num3imp52_$LT$impl$u20$core__fmt__Display$u20$for$u20$i32GT$3fmt17hc51309275f9f171fE ; core::fmt::num::imp::_$LT$impl$u20$core__fmt__Display
mov     [rsp+2E8h+var_288], rax
mov     [rsp+2E8h+var_280], rax
mov     [rsp+2E8h+var_40], rcx
mov     [rsp+2E8h+var_38], rax
mov     rcx, [rsp+2E8h+var_40]
mov     rax, [rsp+2E8h+var_38]
mov     [rsp+2E8h+var_228], rcx
mov     [rsp+2E8h+var_220], rax
mov     rax, rsp
mov     qword ptr [rax+20h], 1

```

```

lea     rdx, off_140022420 ; "x: \n"
lea     rcx, [rsp+2E8h+var_258]
mov     [rsp+2E8h+var_2B8], rcx
mov     r8d, 2
mov     [rsp+2E8h+var_298], r8
lea     r9, [rsp+2E8h+var_228]
call    _ZN4core3fmt9Arguments6new_v117h646cbffa619ae3b3E ; core::fmt::Arguments::new_v1:h646cbffa619ae3b3
mov     rcx, [rsp+2E8h+var_2B8]
call    _ZN3std2io5stdio6_print17h445fdab5382e0576E ; std::io::stdio::_print:h445fdab5382e0576
mov     r8, [rsp+2E8h+var_298]
lea     rcx, [rsp+2E8h+var_268]
mov     [rsp+2E8h+var_10], rcx
lea     rax, _ZN4core3fmt5float52_$LT$impl$u20$core__fmt__Display$u20$for$u20$f64GT$3fmt17hf255ac95ce93dfbbE ; core::fmt::float::_$LT$impl$u20$core__fmt__Display
mov     [rsp+2E8h+var_8], rax
mov     [rsp+2E8h+var_20], rcx
mov     [rsp+2E8h+var_18], rax
mov     rcx, [rsp+2E8h+var_20]
mov     rax, [rsp+2E8h+var_18]
mov     [rsp+2E8h+var_1E8], rcx
mov     [rsp+2E8h+var_1E0], rax
mov     rax, rsp
mov     qword ptr [rax+20h], 1
lea     rdx, off_140022448
lea     rcx, [rsp+2E8h+var_218]
mov     [rsp+2E8h+var_2B0], rcx
lea     r9, [rsp+2E8h+var_1E8]
call    _ZN4core3fmt9Arguments6new_v117h646cbffa619ae3b3E ; core::fmt::Arguments::new_v1:h646cbffa619ae3b3
mov     rcx, [rsp+2E8h+var_2B0]
call    _ZN3std2io5stdio6_print17h445fdab5382e0576E ; std::io::stdio::_print:h445fdab5382e0576
mov     r8, [rsp+2E8h+var_298]
mov     rax, [rsp+2E8h+var_288]
lea     rcx, [rsp+2E8h+var_25C]

```

```

mov     [rsp+2E8h+var_50], rcx
mov     [rsp+2E8h+var_48], rax
mov     [rsp+2E8h+var_60], rcx
mov     [rsp+2E8h+var_58], rax
mov     rcx, [rsp+2E8h+var_60]
mov     rax, [rsp+2E8h+var_58]
mov     [rsp+2E8h+var_1A8], rcx
mov     [rsp+2E8h+var_1A0], rax
mov     rax, rsp
mov     qword ptr [rax+20h], 1
lea     rdx, off_140022470
lea     rcx, [rsp+2E8h+var_1D8]
mov     [rsp+2E8h+var_2A8], rcx
lea     r9, [rsp+2E8h+var_1A8]
call    _ZN4core3fmt9Arguments6new_v117h646cbffa619ae3b3E ; core::fmt::Arguments::new_v1::h646cbffa619ae3b3
mov     rcx, [rsp+2E8h+var_2A8]
call    _ZN3std2io5stdio6_print17h445fdab5382e0576E ; std::io::stdio::_print::h445fdab5382e0576
mov     r8, [rsp+2E8h+var_298]
mov     rax, [rsp+2E8h+var_288]
mov     [rsp+2E8h+var_198], 1
mov     [rsp+2E8h+var_194], 2
mov     [rsp+2E8h+var_190], 3
mov     ecx, [rsp+2E8h+var_198]
mov     [rsp+2E8h+var_18C], ecx
mov     ecx, [rsp+2E8h+var_194]
mov     [rsp+2E8h+var_188], ecx
mov     ecx, [rsp+2E8h+var_190]
mov     [rsp+2E8h+var_184], ecx
lea     rcx, [rsp+2E8h+var_18C]
mov     [rsp+2E8h+var_70], rcx
mov     [rsp+2E8h+var_68], rax
mov     [rsp+2E8h+var_80], rcx

```

```

mov     [rsp+2E8h+var_78], rax
mov     rcx, [rsp+2E8h+var_80]
mov     rax, [rsp+2E8h+var_78]
mov     [rsp+2E8h+var_150], rcx
mov     [rsp+2E8h+var_148], rax
mov     rax, rsp
mov     qword ptr [rax+20h], 1
lea     rdx, off_140022498 ; "one: "
lea     rcx, [rsp+2E8h+var_180]
mov     [rsp+2E8h+var_2A0], rcx
lea     r9, [rsp+2E8h+var_150]
call    _ZN4core3fmt9Arguments6new_v117h646cbffa619ae3b3E ; core::fmt::Arguments::new_v1::h646cbffa619ae3b3
mov     rcx, [rsp+2E8h+var_2A0]
call    _ZN3std2io5stdio6_print17h445fdab5382e0576E ; std::io::stdio::_print::h445fdab5382e0576
mov     r8, [rsp+2E8h+var_298]
mov     rax, [rsp+2E8h+var_288]
lea     rcx, [rsp+2E8h+var_188]
mov     [rsp+2E8h+var_90], rcx
mov     [rsp+2E8h+var_88], rax
mov     [rsp+2E8h+var_A0], rcx
mov     [rsp+2E8h+var_98], rax
mov     rcx, [rsp+2E8h+var_A0]
mov     rax, [rsp+2E8h+var_98]
mov     [rsp+2E8h+var_110], rcx
mov     [rsp+2E8h+var_108], rax
mov     rax, rsp
mov     qword ptr [rax+20h], 1
lea     rdx, off_1400224C0 ; "two: "
lea     rcx, [rsp+2E8h+var_140]
mov     [rsp+2E8h+var_290], rcx
lea     r9, [rsp+2E8h+var_110]
call    _ZN4core3fmt9Arguments6new_v117h646cbffa619ae3b3E ; core::fmt::Arguments::new_v1::h646cbffa619ae3b3

```

```

mov     rcx, [rsp+2E8h+var_290]
call    _ZN3std2io5stdio6_print17h445fdab5382e0576E ; std::io::stdio::_print::h445fdab5382e0576
mov     rax, [rsp+2E8h+var_288]
lea     rcx, [rsp+2E8h+var_184]
mov     [rsp+2E8h+var_B0], rcx
mov     [rsp+2E8h+var_A8], rax
mov     [rsp+2E8h+var_C0], rcx
mov     [rsp+2E8h+var_B8], rax
mov     rcx, [rsp+2E8h+var_C0]
mov     rax, [rsp+2E8h+var_B8]
mov     [rsp+2E8h+var_D0], rcx
mov     [rsp+2E8h+var_C8], rax
lea     rcx, [rsp+2E8h+var_100]
lea     rdx, off_1400224E8 ; "three: "
mov     r8d, 2
lea     r9, [rsp+2E8h+var_D0]
mov     [rsp+2E8h+var_2C8], 1
call    _ZN4core3fmt9Arguments6new_v117h646cbffa619ae3b3E ; core::fmt::Arguments::new_v1::h646cbffa619ae3b3
lea     rcx, [rsp+2E8h+var_100]
call    _ZN3std2io5stdio6_print17h445fdab5382e0576E ; std::io::stdio::_print::h445fdab5382e0576
nop
add     rsp, 2E8h
retn
three_compound_data_types__main endp

```

Ok... I know this can be completely overwhelming but again like all of the other Reverse Engineering & Hacking (REDAH) tutorials I have made over the years we will take it one step at a time!

We see the below instruction.

```
mov [rsp+2E8h+var_278], 539h
```

We remember in our source code our first tuple value is 1337. Therefore 0x539 is 1337.

We then see a call to the *println!* macro to print this value.

```
call _ZN3std2io5stdio6_print17h445fdab5382e0576E ; std::io::stdio::print::h445fdab5382e0576
```

Next we are going to handle the next tuple value of 3.14.

Let's set a breakpoint at the below and run.

```
.text:00007FF66657135F lea rcx, [rsp+2E8h+var_268]
```

Let's take a step with F8 and double-click on the *[rsp+2E8h+var_268]* value.

We see the values on the stack below.

```
Stack[0000398C]:0000007B3375F970 db 1Fh
Stack[0000398C]:0000007B3375F971 db 85h
Stack[0000398C]:0000007B3375F972 db 0EBh
Stack[0000398C]:0000007B3375F973 db 51h
Stack[0000398C]:0000007B3375F974 db 0B8h
Stack[0000398C]:0000007B3375F975 db 1Eh
Stack[0000398C]:0000007B3375F976 db 9
Stack[0000398C]:0000007B3375F977 db 40h
```

Let's convert the hex values to binary.

```
1Fh -> 00011111
85h -> 10000101
0EBh -> 000011101011
51h -> 01010001
0B8h -> 000010111000
1Eh -> 00011110
09 -> 00001001
40h -> 01000000
```

```
00011111 10000101 000011101011 01010001 000010111000 00011110 00001001 01000000
```

This binary sequence represents the 64-bit double-precision floating-point number according to the IEEE 754 standard.

- ```
* Sign bit: 0 (positive)
* Exponent: 0001111101 (1021 in decimal)
* Significand: 1.0100001100010000000000000000000000000000000000000
```

When you convert this binary representation to decimal, it is approximately equal to 3.14.

We then see a call to the *println!* macro to print this value.

```
.text:00007FF6665713DF call ZN3std2io5stdio6 print17h445fdab5382e0576E ; std::io::stdio::print::h445fdab5382e0576
```

Next we are going to handle the next tuple value of 42.

Let's set a breakpoint on the below.

```
.text:00007FF6665713EE lea rcx, [rsp+2E8h+var_25C]
```

Let's F8 and step over.

Let's examine the values within `[rsp+2E8h+var_25C]`.

```
Stack[0000398C]:0000007B3375F97C db 2Ah
```

We know 42 is 0x2a in hex.

We then see a call to the *println!* macro to print this value.

```
text:00007FF666571467 call ZN3std2io5stdio6 print17h445fdab5382e0576E : std::io::stdio:: print::h445fdab5382e0576
```

Next we are going to handle the array values of 1, 2 and 3.

We see them all being placed into offsets of the stack.

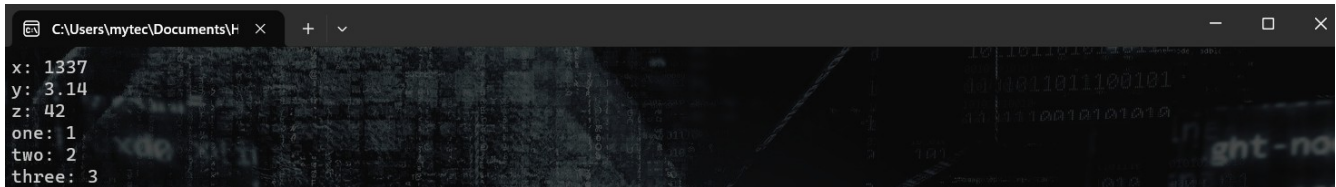
```
text:00007FF666571476 mov [rsp+2E8h+var_198], 1
text:00007FF666571481 mov [rsp+2E8h+var_194], 2
text:00007FF66657148C mov [rsp+2E8h+var_190], 3
```



We then see the three calls to the *println!* macro which are spaced out in the Assembler.

```
.text:00007FF66657153A call _ZN3std2io5stdio6_print17h445fdab5382e0576E ; std::io::stdio::_print::h445fdab5382e0576E
.text:00007FF6665715C2 call _ZN3std2io5stdio6_print17h445fdab5382e0576E ; std::io::stdio::_print::h445fdab5382e0576E
.text:00007FF666571647 call _ZN3std2io5stdio6_print17h445fdab5382e0576E ; std::io::stdio::_print::h445fdab5382e0576E
```

This prints the following to the terminal.



```
C:\Users\mytec\Documents\H x + v
x: 1337
y: 3.14
z: 42
one: 1
two: 2
three: 3
```

In our next lesson we will hack this!

## Chapter 9: Hacking Compound Data Types

Let's hack our app within IDA Free.

Open IDA Free and we see the load screen. We can keep all the defaults and simply click OK.

On the left-hand side we see the Function name window and we want to search for *three\_compound\_data\_types\_\_main*. Double-click it and we will see the function.

We see the first part of our program which is the first tuple value of 1337.

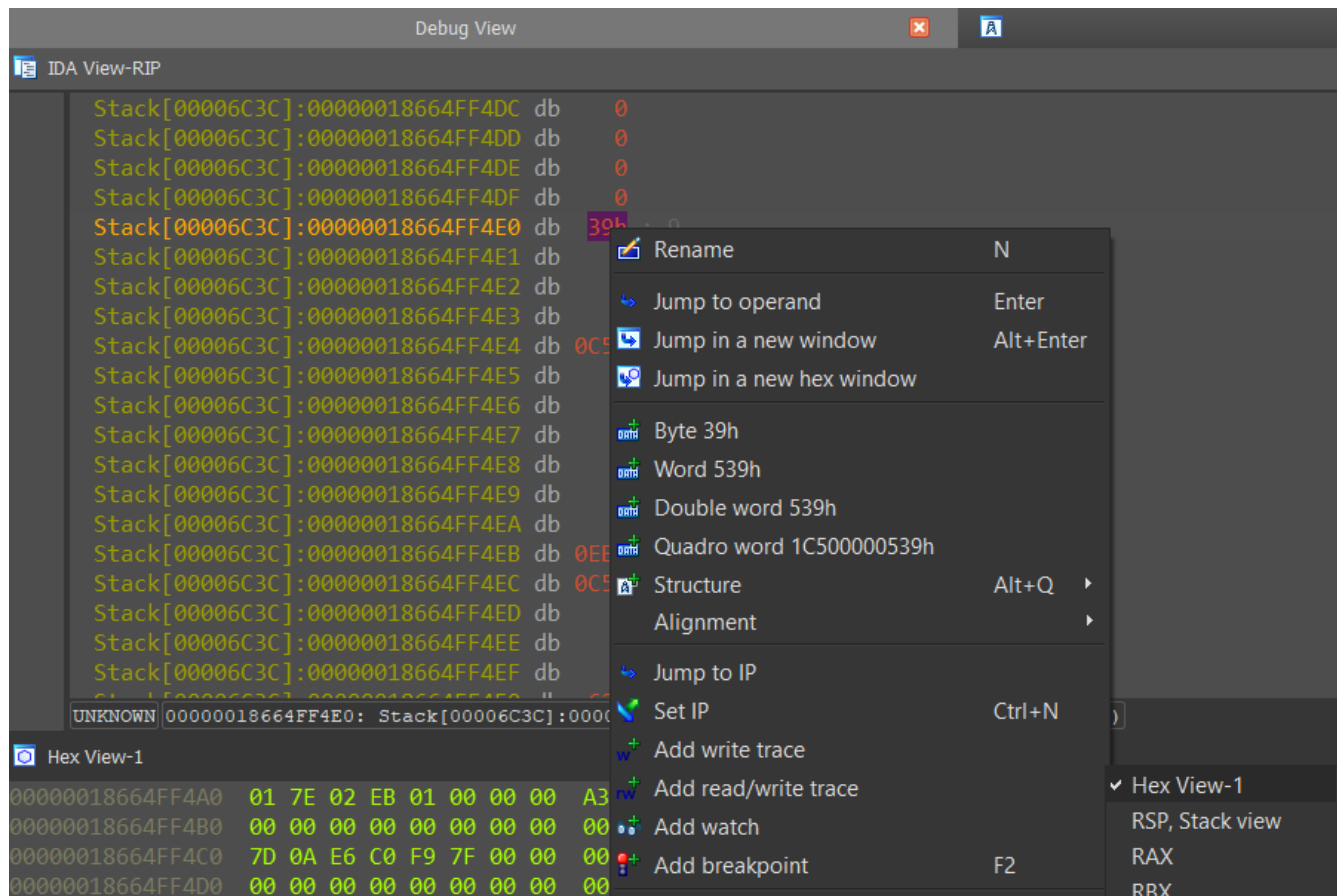
```
mov [rsp+2E8h+var_278], 539h
```

Let's set a breakpoint on the next line after this and run.

```
.text:00007FF75DF41287 mov [rsp+2E8h+var_278], 539h
.text:00007FF75DF4128F mov rax, 40091EB851EB851Fh
```

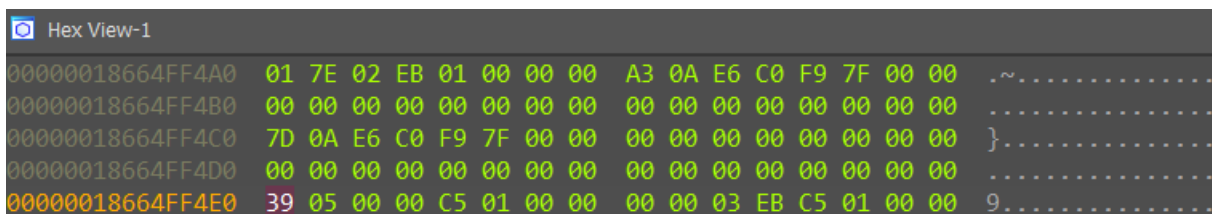
Let's double-click in the *[rsp+2E8h+var\_278]*.

It is important to have the hex view synced with our instructions.



We see a *db* 5 and then above it *db* 39 so this is our 0x539 value we are going to hack.

Right-click on the hex view where the 39 is.



Press F2 and it will turn grey and type 40.

Then press F2 again and it will turn green again.

Let's continue and see the result!



Success! We hacked the first part!

This is a different way to hack the variable as this was a RAM hack within our stack. This will not stay persistent on a re-run of the program but I wanted to show you yet another way to make a hack if you are attached to a running binary.

Let's stop our debugging session and click on the Hex View-1 tab and make sure the below line is selected first.

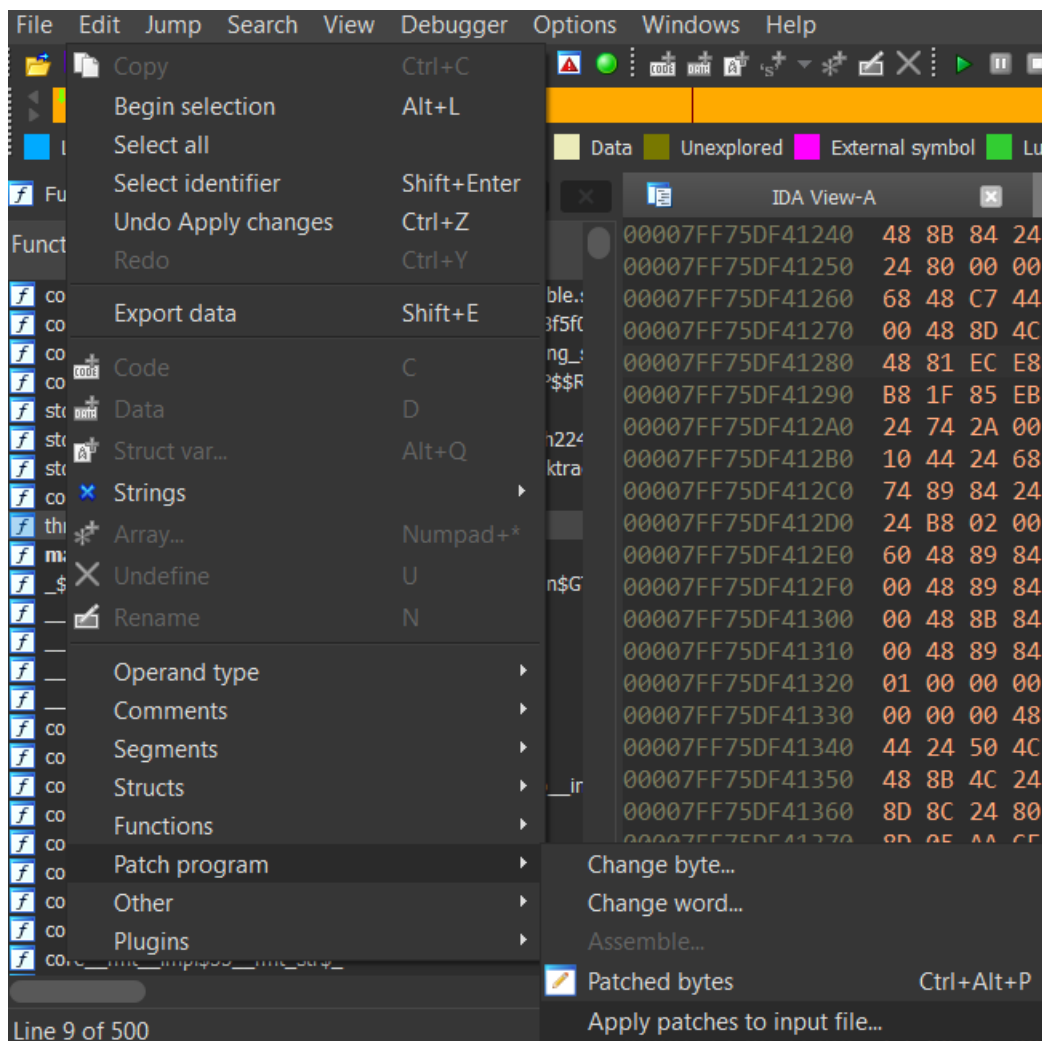
```
mov [rsp+2E8h+var_278], 530h
```

In the Hex View-1 tab.

```
00007FF75DF41280 48 81 EC E8 02 00 00 C7 44 24 70 39 05 00 00 48 H.....$p9...H
```

Press F2 and type 06 and then press F2 again as it should go grey and then back to orange.

Then click *Edit* then *Patch program* then *Apply patches to input file...*



Now it will permanently change the binary. I deliberately changed the *06* this time to show the difference when we run.



To hack the value of the 3.14 tuple we have to take a step back and see what is happening in our binary. We know that in our debugging session we found the values inside `var_268` to be the below.

```
1Fh -> 00011111
85h -> 10000101
0EBh -> 000011101011
51h -> 01010001
0B8h -> 000010111000
1Eh -> 00011110
09 -> 00001001
40h -> 01000000
```

00011111 10000101 000011101011 01010001 000010111000 00011110 00001001 01000000

This binary sequence represents the 64-bit double-precision floating-point number according to the IEEE 754 standard.

- \* Sign bit: 0 (positive)
- \* Exponent: 0001111101 (1021 in decimal)
- \* Significand: 1.010000110001000000000000000000000000000000000000000000000000000000

When you convert this binary representation to decimal, it is approximately equal to 3.14.

At the beginning of our main function we see variables being init with offsets and then we see this strange value being moved into `rax` below.

```
mov rax, 40091EB851EB851Fh
```

Let's highlight it and look in our Hex View-1 tab.

```
00007FF756A01280 48 81 EC E8 02 00 00 C7 44 24 70 39 06 00 00 48 H.....$p9...H
00007FF756A01290 B8 1E 85 EB 51 B8 1E 09 40 48 89 44 24 68 C7 44 @H D$h
```

BOOM!

Let's change `1F` to `1E` and patch and run.



To hack the next tuple value of 42 we have to locate the `0x2A` value at the top of our binary and patch it to `0x2B`. Since you have seen many examples of how to do this I will show the patched binary line.

```
mov [rsp+2E8h+var_274], 2Bh
```

When we run we see the value of 43 now.



Finally we have our array values of 1, 2 and 3.

```
mov [rsp+2E8h+var_198], 1
mov [rsp+2E8h+var_194], 2
mov [rsp+2E8h+var_190], 3
```

As we look at the hex please look for the patterns of 01 00 00 00 and then within the next byte 02 00 00 00 and then within the next byte 03 00 00 00.

|                  |                                                 |                    |
|------------------|-------------------------------------------------|--------------------|
| 00007FF7F17F11F0 | 50 48 8B 44 24 60 C7 84 24 50 01 00 00 01 00 00 | PH.D\$`0P.....     |
| 00007FF7F17F1200 | 00 C7 84 24 54 01 00 00 02 00 00 00 C7 84 24 58 | .0P.\$T.....0P.\$X |
| 00007FF7F17F1210 | 01 00 00 03 00 00 00 8B 8C 24 50 01 00 00 89 8C | .....\$P.....      |

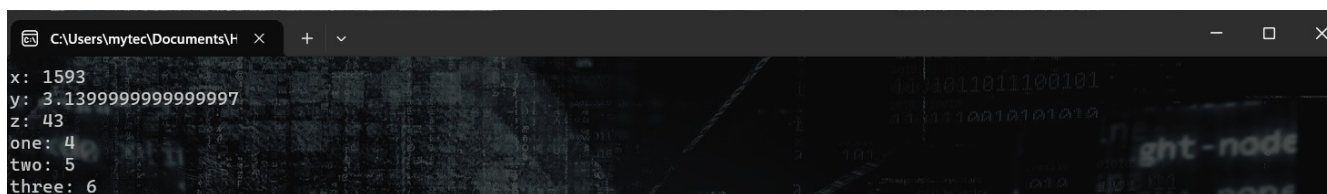
We need to change the 01 to 04 and the 02 to 05 and the 03 to 06.

```
mov [rsp+2E8h+var_198], 4
mov [rsp+2E8h+var_194], 5
mov [rsp+2E8h+var_190], 6
```

We can see the patched bytes.

|                  |                                                 |                    |
|------------------|-------------------------------------------------|--------------------|
| 00007FF769DB11F0 | 50 48 8B 44 24 60 C7 84 24 50 01 00 00 04 00 00 | PH.D\$`0P.....     |
| 00007FF769DB1200 | 00 C7 84 24 54 01 00 00 05 00 00 00 C7 84 24 58 | .0P.\$T.....0P.\$X |
| 00007FF769DB1210 | 01 00 00 06 00 00 00 8B 8C 24 50 01 00 00 89 8C | .....\$P.....      |

Let's run!



Hooray! We hacked it!

In our next lesson we will cover functions.