BigIsim04's puzzle — Reverse Engineering Write-up

Challenge link: https://crackmes.one/crackme/691de1d12d267f28f69b7f16
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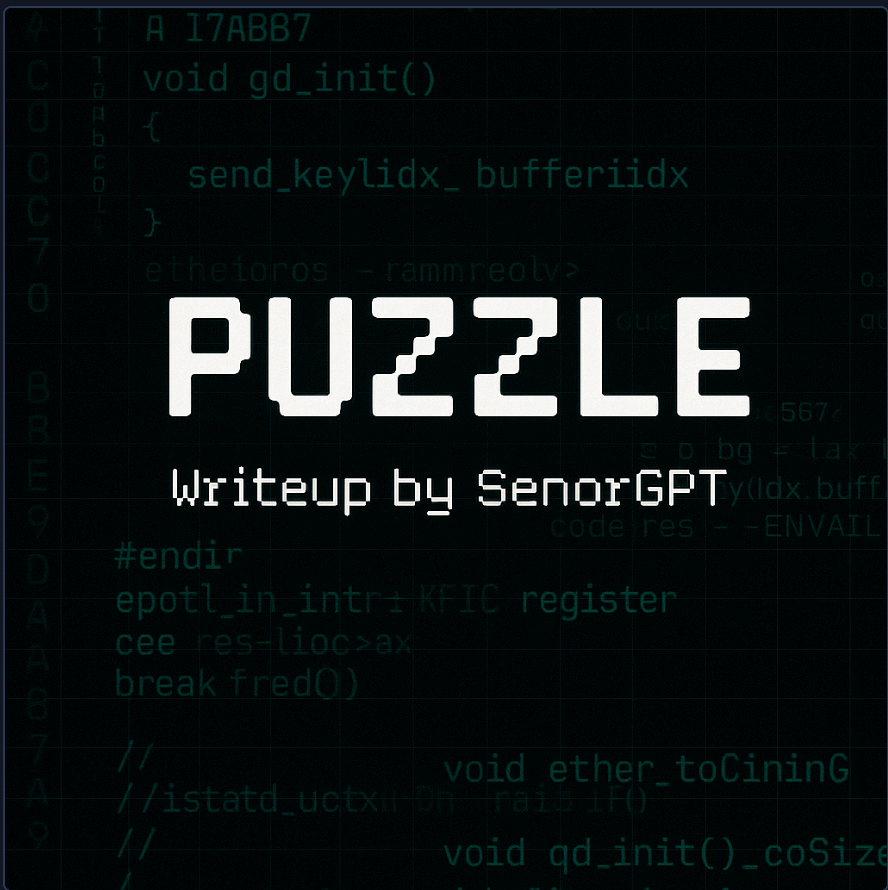
Write-up by: *SenorGPT*
Tools used: *CFF Explorer, Detect It Easy (DIE), x64dbg*

Platform	Difficulty	Quality	Arch	Language
Windows	2.5	3.5	x86-64	C/C++



Status: Complete
Goal: Document a clean path from initial recon → locating key-check logic → validation/reversal strategy

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1. Executive Summary

This document captures my reverse-engineering process for the crackme `puzzle` by `Biglsim04`. The target appears to be a simple command line process that prompts the user for a password.

I successfully:

- Performed basic static reconnaissance.
- Surveyed imports. Confirmed there appears to be anti-debugging measures.
- Tried to locate strings associated with success & failure dialogs.
- Added breakpoints on functions that may be used for anti-debugging and begun to trace logic.
- Discovered the input validation and reverse engineered the encoding and comparison logic.

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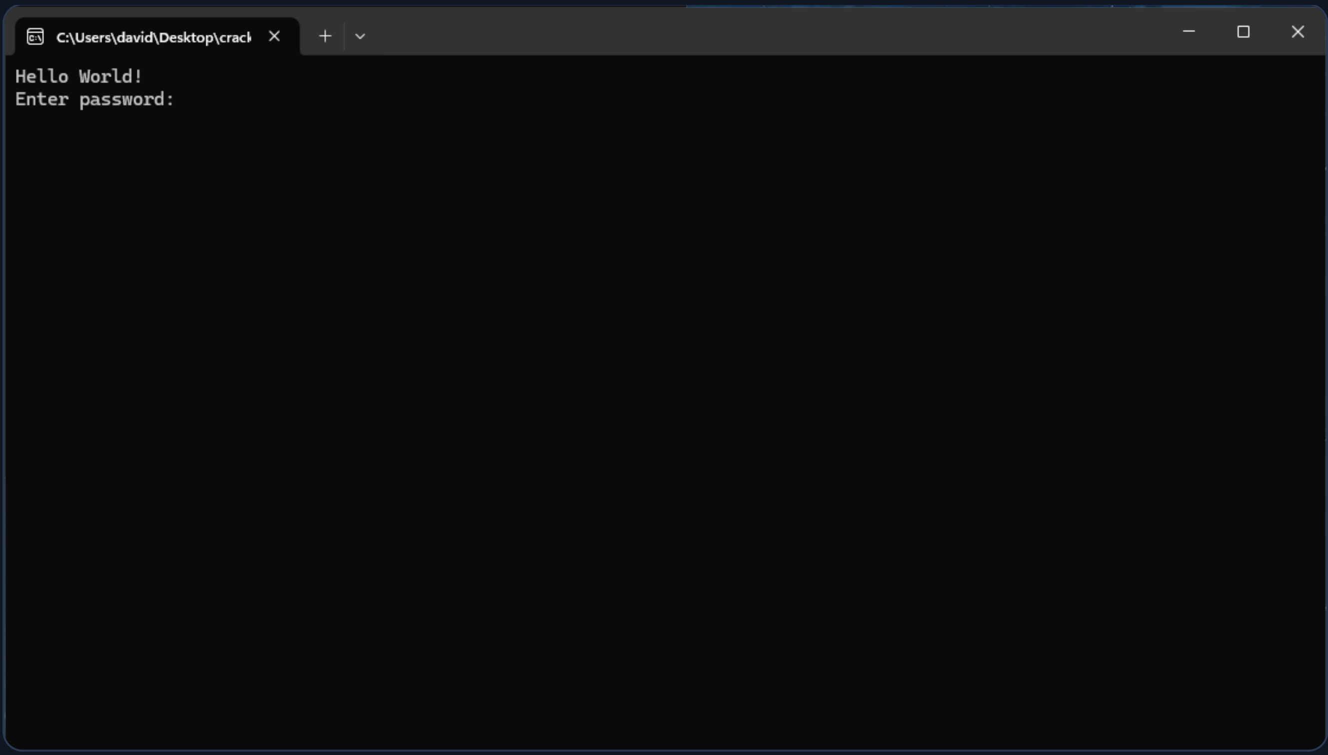
2. Target Overview

2.1 UI / Behaviour

- Inputs: *Enter password:*
- Outputs: *Access Denied*, *Access Accepted* (assumption based on wrong answer string).

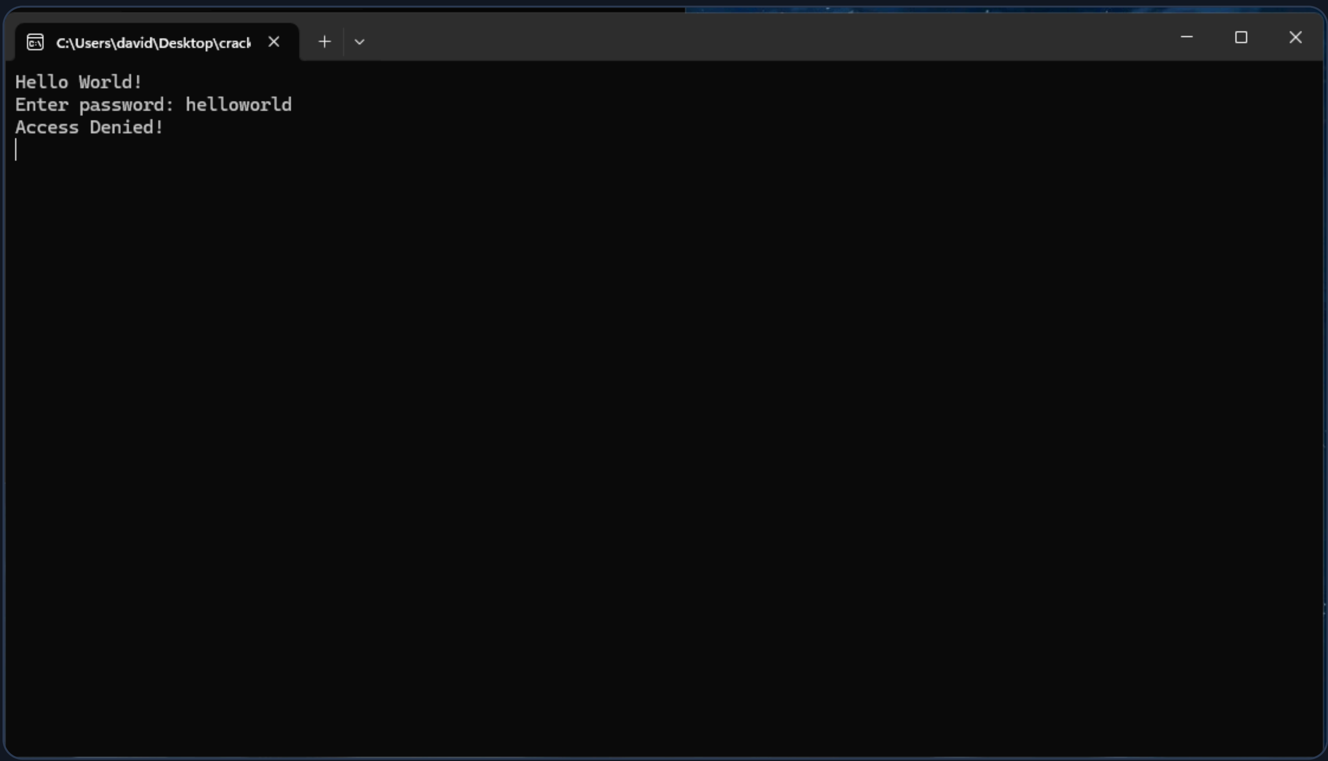
2.2 Screens

2.2.1 Start-up



2.2.2 Failure case

Followed by exit on next key input.



3. Tooling & Environment

- OS: *Windows 11*
- Debugger: *x64dbg*
- Static tools: *CFF Explorer, Detect It Easy (DIE)*

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4. Static Recon

4.1 File & Headers

There appears to be no obvious signs of packing or obfuscation. The classic boring set of sections `.text`, `.rdata`, `.data`, `.reloc` represent a very typical layout for an unprotected Visual Studio type Portable Executable (*PE*).
The sizes also seem reasonable for a small console application.

puzzle.exe

Name	Virtual Size	Virtual Address	Raw Size	Raw Address	Reloc Address	Linenumbers	Relocations N...	Linenumbers ...	Characteristics
Byte[8]	Dword	Dword	Dword	Dword	Dword	Dword	Word	Word	Dword
.text	00020000	00001000	0001FE00	00000400	00000000	00000000	0000	0000	60000020
.rdata	0000F000	00021000	0000EC00	00020200	00000000	00000000	0000	0000	40000040
.data	00008000	00030000	00001400	0002EE00	00000000	00000000	0000	0000	C0000040
.reloc	00000934	00038000	00000A00	00030200	00000000	00000000	0000	0000	42000040

Packed binaries often show one or more of these red flags:

- **Weird section names:**
  `.UPX0, .UPX1, .aspack, .petite`, or just random gibberish.
- **Very few sections:**
  Sometimes just one or two suspicious ones.
- **Abnormal size balance:**
  A tiny `.text` with a huge other section holding compressed payload.

It is *IMPORTANT* to note that headers alone can not confirm if the *PE* has been packed or obfuscated as the packer/obfuscator used might utilize normal looking section names, keep a standard layout, and/or hide the real tell in entropy or runtime behaviour.

4.2 Entropy

Entropy is a measure of how *random-looking* the bytes are in a section.

- Low entropy = looks like normal code/data (more patterns, more repetition).
- High entropy = looks compressed or encrypted (more random).

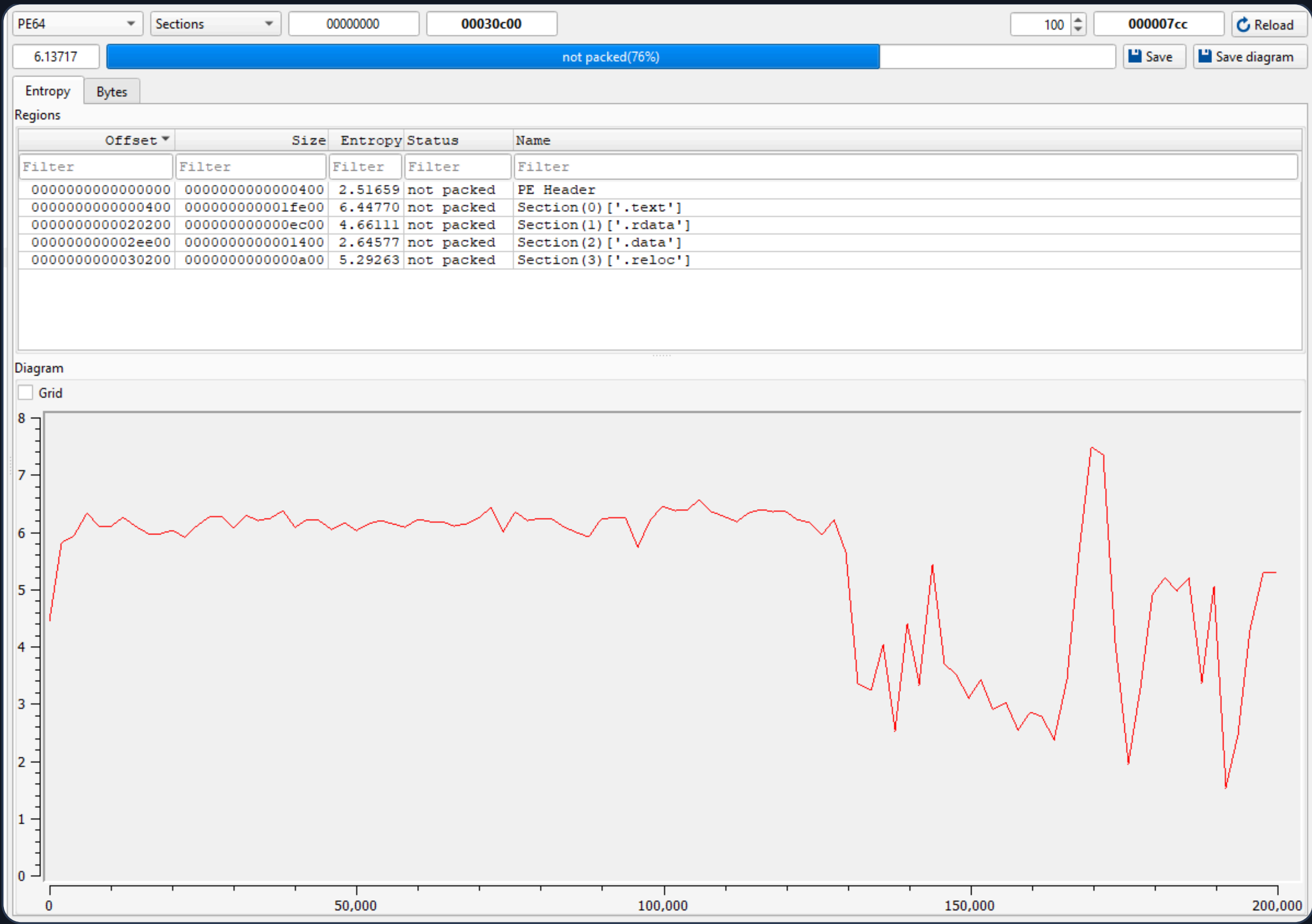
Why this matters:

- Packed or encrypted payloads often have high entropy.
- Normal `.text` code usually has moderate entropy.

Rule of thumb (quick reference, not 100%):

- ~6.0–7.2 = often normalish
- ~7.4–8.0 = suspicious for compression/encryption

Unfortunately, *CFF Explorer* does not have an entropy viewer so I switch to *DIE*.



The top blue bar shows *DIE*'s overall heuristic guess based mostly on entropy patterns and layout. This is not necessarily proof, but a strong hint that this is not classically packed.

The table shows each row as a region - header + each *PE* section - with an entropy score.

Section Name	Entropy Score	Note
PE Header	2.51659	Low entropy is normal for headers.
.text	6.44770	normal looking code entropy. If this was packed or encrypted the value would be closer to ~7.5–8.0.
.rdata	4.66111	Normal for constants/strings/tables.
.data	2.64577	Very normal (initialized globals).
.reloc	5.29263	Also not unusual.

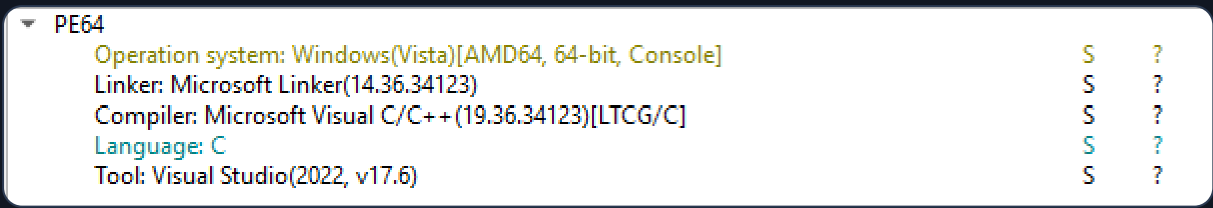
Nothing here also seems to scream that this *PE* is packed.

Finally, the graph represents a rolling entropy line across the file from start to end. The long flatish area around *~6* matches the `.text` region.
The later dips and spikes reflect transitions into `.rdata`, `.data`, `.reloc`.

Again, if this *PE* was packed the graph would have a big chunk of the line hovering around *~7.4-8*.

4.3 Build & Toolchain Information

Screenshot summary provided by *DIE*



Operation system: Windows(Vista)AMD64, 64-bit, Console
The binary is a *64-bit Windows console app*. The *Vista* part usually reflects the *minimum subsystem version* or tool heuristics and *NOT* that it only runs on Vista.

Linker: Microsoft Linker (14.36.34123)
The exact *MSVC linker version* used to produce the EXE.

Compiler: Microsoft Visual C/C++ (19.36.34123) [LTCG/C]
Identifies the *Visual C++ compiler version*.
LTCG = *Link-Time Code Generation* (whole-program optimization). The `/C` part is just the tool's way of labelling the language/compile family.

Language: C
DIE's best guess for source language. In practice, this likely means *C or C++* with a C-like signature.

Tool: Visual Studio(2022, v17.6)
Maps those version numbers to the likely *IDE/toolchain family* that was used to build the *EXE*.

4.4 Imports / Exports

Since it is a simple console application, the only import *SEEMS* to be `KERNEL32.dll`.

OFTs	FTs (IAT)	Hint	Name
Qword	Qword	Word	szAnsi
000000000002F3E0	000000000002F3E0	0337	GetTickCount64
000000000002F3F2	000000000002F3F2	0336	GetTickCount
000000000002FA0E	000000000002FA0E	0657	WriteConsoleW
000000000002F410	000000000002F410	047B	QueryPerformanceCounter
000000000002F42A	000000000002F42A	023C	GetCurrentProcessId
000000000002F440	000000000002F440	0240	GetCurrentThreadId
000000000002F456	000000000002F456	0314	GetSystemTimeAsFileTime
000000000002F470	000000000002F470	0394	InitializeSListHead
000000000002F486	000000000002F486	0501	RtlCaptureContext
000000000002F49A	000000000002F49A	0509	RtlLookupFunctionEntry
000000000002F4B4	000000000002F4B4	0510	RtlVirtualUnwind
000000000002F4C8	000000000002F4C8	03AA	IsDebuggerPresent
000000000002F4DC	000000000002F4DC	05F3	UnhandledExceptionFilter
000000000002F4F8	000000000002F4F8	05B0	SetUnhandledExceptionFilter
000000000002F516	000000000002F516	02FB	GetStartupInfoW
000000000002F528	000000000002F528	03B2	IsProcessorFeaturePresent
000000000002F544	000000000002F544	029F	GetModuleHandleW
000000000002F558	000000000002F558	0151	EnterCriticalSection
000000000002F570	000000000002F570	03EA	LeaveCriticalSection
000000000002F588	000000000002F588	0391	InitializeCriticalSectionEx
000000000002F5A6	000000000002F5A6	012B	DeleteCriticalSection
000000000002F5BE	000000000002F5BE	014D	EncodePointer
000000000002F5CE	000000000002F5CE	0124	DecodePointer
000000000002F5DE	000000000002F5DE	041D	MultiByteToWideChar
000000000002F5F4	000000000002F5F4	0644	WideCharToMultiByte
000000000002F60A	000000000002F60A	03DD	LCMapStringEx
000000000002F61A	000000000002F61A	0302	GetStringTypeW
000000000002F62C	000000000002F62C	01E4	GetCPInfo
000000000002F638	000000000002F638	050F	RtlUnwindEx
000000000002F646	000000000002F646	050B	RtlPcToFileHeader

OFTs	FTs (IAT)	Hint	Name
0002E408	000202E8	0002E846	0002E848
Qword	Qword	Word	szAnsi
000000000002F65A	000000000002F65A	0492	RaiseException
000000000002F66C	000000000002F66C	0287	GetLastError
000000000002F67C	000000000002F67C	0570	SetLastError
000000000002F68C	000000000002F68C	0390	InitializeCriticalSectionAndSpinCou...
000000000002F6B4	000000000002F6B4	05E2	TlsAlloc
000000000002F6C0	000000000002F6C0	05E4	TlsGetValue
000000000002F6CE	000000000002F6CE	05E6	TlsSetValue
000000000002F6DC	000000000002F6DC	05E3	TlsFree
000000000002F6E6	000000000002F6E6	01CE	FreeLibrary
000000000002F6F4	000000000002F6F4	02D7	GetProcAddress
000000000002F706	000000000002F706	03F0	LoadLibraryExW
000000000002F718	000000000002F718	023B	GetCurrentProcess
000000000002F72C	000000000002F72C	05D0	TerminateProcess
000000000002F740	000000000002F740	02FD	GetStdHandle
000000000002F750	000000000002F750	0658	WriteFile
000000000002F75C	000000000002F75C	029B	GetModuleFileNameW
000000000002F772	000000000002F772	0180	ExitProcess
000000000002F780	000000000002F780	029E	GetModuleHandleExW
000000000002F796	000000000002F796	01F9	GetCommandLineA
000000000002F7A8	000000000002F7A8	01FA	GetCommandLineW
000000000002F7BA	000000000002F7BA	037A	HeapFree
000000000002F7C6	000000000002F7C6	0274	GetFileType
000000000002F7D4	000000000002F7D4	0376	HeapAlloc
000000000002F7E0	000000000002F7E0	0197	FindClose
000000000002F7EC	000000000002F7EC	019D	FindFirstFileExW
000000000002F800	000000000002F800	01AE	FindNextFileW
000000000002F810	000000000002F810	03B8	IsValidCodePage
000000000002F822	000000000002F822	01D5	GetACP
000000000002F82C	000000000002F82C	02C0	GetOEMCP
000000000002F838	000000000002F838	025C	GetEnvironmentStringsW
000000000002F852	000000000002F852	01CD	FreeEnvironmentStringsW
000000000002F86C	000000000002F86C	0552	SetEnvironmentVariableW
000000000002F886	000000000002F886	058B	SetStdHandle
000000000002F896	000000000002F896	028B	GetLocaleInfoW
000000000002F8A8	000000000002F8A8	03BA	IsValidLocale
000000000002F8B8	000000000002F8B8	0343	GetUserDefaultLCID
000000000002F8CE	000000000002F8CE	0175	EnumSystemLocalesW
000000000002F8E4	000000000002F8E4	01BC	FlsAlloc
000000000002F8F0	000000000002F8F0	01BE	FlsGetValue
000000000002F8FE	000000000002F8FE	01C0	FlsSetValue
000000000002F90C	000000000002F90C	01BD	FlsFree
000000000002F916	000000000002F916	0612	VirtualProtect
000000000002F928	000000000002F928	00B2	CompareStringW
000000000002F93A	000000000002F93A	03DE	LCMapStringW
000000000002F94A	000000000002F94A	02DE	GetProcessHeap
000000000002F95C	000000000002F95C	009C	CloseHandle
000000000002F96A	000000000002F96A	01C2	FlushFileBuffers
000000000002F97E	000000000002F97E	0223	GetConsoleOutputCP
000000000002F994	000000000002F994	021F	GetConsoleMode
000000000002F9A6	000000000002F9A6	04A3	ReadFile
000000000002F9B2	000000000002F9B2	0272	GetFileSizeEx
000000000002F9C2	000000000002F9C2	0561	SetFilePointerEx
000000000002F9D6	000000000002F9D6	04A0	ReadConsoleW
000000000002F9E6	000000000002F9E6	037D	HeapReAlloc
000000000002F9F4	000000000002F9F4	037F	HeapSize
000000000002FA00	000000000002FA00	00E2	CreateFileW
000000000002FA1E	000000000002FA1E	050E	RtlUnwind

4.4.1 KERNEL32.dll

Off the bat I notice at least one *VERY* interesting function that is commonly used as a direct check for anti-debugging, `IsDebuggerPresent`.

Other functions that caught my eye are the timing functions; `QueryPerformanceCounter`, `GetTickCount`, `GetTickCount64`, `GetSystemTimeAsFileTime`. These aren't necessarily indicative of anything, but *could* be used to support debugger detection logic by performing timing checks.

`GetCurrentProcessId`, `GetStartupInfoW`, and `GetCurrentThreadId` *could* also be used as anti-debug logic to check for certain flags or conditions on the program itself.

`LoadLibraryExW`, `GetProcAddress` and `FreeLibrary` *could* be used to hide libraries/modules by dynamic resolution.

`GetLastError`, `SetLastError`, `RaiseException`, `UnhandledExceptionFilter`, and `SetUnhandledExceptionFilter` *could* all be used in exception based anti-debugging measures.

`IsProcessorFeaturePresent` is also interesting as it *could* be used for certain anti-debug exception tricks.

`VirtualProtect` is often used for unpacking, self-modifying code, patching stubs, and flipping page protections around anti-debug regions.

Some additional functions that are not in the import table from `KERNEL32.dll` that might be worth adding breakpoints to are; `CheckRemoteDebuggerPresent`, `OutputDebugStringA/W`, `NtQueryInformationProcess`

Furthermore, adding breakpoints on `NTDLL.DLL` functions that are used for anti-debug logic just in case; `NtQueryInformationProcess`, `NtSetInformationThread`, and `RtlAddVectoredExceptionHandler` / `RtlRemoveVectoredExceptionHandler`.

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5. Dynamic Analysis

5.1 String-Driven Entry

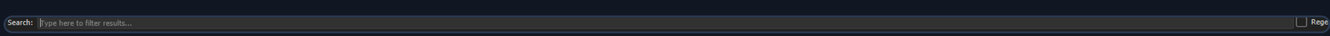
Starting the program in *x64dbg* to see if any immediate anti-debug code triggers yields nothing, yet...

As always, my first point of attack is a string-driven entry. Searching for string references in *x64dbg* yields the following results:
(Specifically looking for strings that I observed during start-up and failure case; `Hello World!`, `Enter password:`, and `Access Denied!`)

Address	Disassembly	String Address	String
00007FF621CA1354	lea rax,qword ptr ds:[7FF621CCB560]	00007FF621CCB560	"Unknown exception"
00007FF621CA13E0	lea rax,qword ptr ds:[7FF621CCB578]	00007FF621CCB578	"bad array new length"
00007FF621CA14B4	lea rcx,qword ptr ds:[7FF621CCB590]	00007FF621CCB590	"string too long"
00007FF621CA16EC	lea r9,qword ptr ds:[7FF621CCB5A0]	00007FF621CCB5A0	": "
00007FF621CA1980	lea rax,qword ptr ds:[7FF621CCB5A8]	00007FF621CCB5A8	"iostream"
00007FF621CA19CC	movups xmm0,xmmword ptr ds:[7FF621CCB638]	00007FF621CCB638	"iostream stream error"
00007FF621CA19D6	mov ecx,dword ptr ds:[7FF621CCB648]	00007FF621CCB648	"error"
00007FF621CA1A70	lea rax,qword ptr ds:[7FF621CCB5B8]	00007FF621CCB5B8	"bad cast"
00007FF621CA1B93	lea rcx,qword ptr ds:[7FF621CCB5C8]	00007FF621CCB5C8	"bad locale name"
00007FF621CA2B56	lea rbx,qword ptr ds:[7FF621CCB5E0]	00007FF621CCB5E0	"ios_base::badbit set"
00007FF621CA2B62	lea rbx,qword ptr ds:[7FF621CCB5F8]	00007FF621CCB5F8	"ios_base::failbit set"
00007FF621CA2B69	lea rax,qword ptr ds:[7FF621CCB610]	00007FF621CCB610	"ios_base::eofbit set"
00007FF621CA2C53	lea rbx,qword ptr ds:[7FF621CCB5E0]	00007FF621CCB5E0	"ios_base::badbit set"
00007FF621CA2C5E	lea rbx,qword ptr ds:[7FF621CCB5F8]	00007FF621CCB5F8	"ios_base::failbit set"
00007FF621CA2C65	lea rax,qword ptr ds:[7FF621CCB610]	00007FF621CCB610	"ios_base::eofbit set"
00007FF621CA2DA7	lea rbx,qword ptr ds:[7FF621CCB5E0]	00007FF621CCB5E0	"ios_base::badbit set"
00007FF621CA2DB2	lea rbx,qword ptr ds:[7FF621CCB5F8]	00007FF621CCB5F8	"ios_base::failbit set"
00007FF621CA2DB9	lea rax,qword ptr ds:[7FF621CCB610]	00007FF621CCB610	"ios_base::eofbit set"
00007FF621CA2F90	lea rbx,qword ptr ds:[7FF621CCB5E0]	00007FF621CCB5E0	"ios_base::badbit set"
00007FF621CA2F9C	lea rbx,qword ptr ds:[7FF621CCB5F8]	00007FF621CCB5F8	"ios_base::failbit set"
00007FF621CA2FA3	lea rax,qword ptr ds:[7FF621CCB610]	00007FF621CCB610	"ios_base::eofbit set"
00007FF621CA3265	lea rcx,qword ptr ds:[7FF621CCB5C8]	00007FF621CCB5C8	"bad locale name"
00007FF621CA3529	lea rbx,qword ptr ds:[7FF621CCB5E0]	00007FF621CCB5E0	"ios_base::badbit set"
00007FF621CA3534	lea rbx,qword ptr ds:[7FF621CCB5F8]	00007FF621CCB5F8	"ios_base::failbit set"
00007FF621CA353B	lea rax,qword ptr ds:[7FF621CCB610]	00007FF621CCB610	"ios_base::eofbit set"
00007FF621CA3BC4	lea rcx,qword ptr ds:[7FF621CCB628]	00007FF621CCB628	"vector too long"
00007FF621CA43A9	lea rax,qword ptr ds:[7FF621CC1460]	00007FF621CC1460	"bad allocation"
00007FF621CA5880	lea rbx,qword ptr ds:[7FF621CCB5E0]	00007FF621CCB5E0	"ios_base::badbit set"
00007FF621CA588C	lea rbx,qword ptr ds:[7FF621CCB5F8]	00007FF621CCB5F8	"ios_base::failbit set"
00007FF621CA5893	lea rax,qword ptr ds:[7FF621CCB610]	00007FF621CCB610	"ios_base::eofbit set"
00007FF621CA5A38	lea rbx,qword ptr ds:[7FF621CCB5E0]	00007FF621CCB5E0	"ios_base::badbit set"
00007FF621CA5A43	lea rbx,qword ptr ds:[7FF621CCB5F8]	00007FF621CCB5F8	"ios_base::failbit set"
00007FF621CA5A4A	lea rax,qword ptr ds:[7FF621CCB610]	00007FF621CCB610	"ios_base::eofbit set"
00007FF621CA6C5B	lea rcx,qword ptr ds:[7FF621CC17E8]	00007FF621CC17E8	"invalid random_device value"
00007FF621CA6C77	lea rdx,qword ptr ds:[7FF621CC1FA0]	00007FF621CC1FA0	"success"
00007FF621CA6C83	lea rax,qword ptr ds:[7FF621CC2658]	00007FF621CC2658	"unknown error"
00007FF621CAAB85	lea rax,qword ptr ds:[7FF621CC3778]	00007FF621CC3778	"bad exception"
00007FF621CABBA5	lea rdx,qword ptr ds:[7FF621CC3838]	00007FF621CC3838	L"api-ms-"
00007FF621CABC59	lea r9,qword ptr ds:[7FF621CC3850]	00007FF621CC3850	"FlsAlloc"
00007FF621CABC69	lea rdx,qword ptr ds:[7FF621CC3850]	00007FF621CC3850	"FlsAlloc"
00007FF621CABCA0	lea r9,qword ptr ds:[7FF621CC3868]	00007FF621CC3868	"FlsFree"
00007FF621CABCB3	lea rdx,qword ptr ds:[7FF621CC3868]	00007FF621CC3868	"FlsFree"
00007FF621CABCE8	lea r9,qword ptr ds:[7FF621CC3878]	00007FF621CC3878	"FlsGetValue"
00007FF621CABCFB	lea rdx,qword ptr ds:[7FF621CC3878]	00007FF621CC3878	"FlsGetValue"
00007FF621CABD35	lea r9,qword ptr ds:[7FF621CC3890]	00007FF621CC3890	"FlsSetValue"
00007FF621CABD3E	lea rdx,qword ptr ds:[7FF621CC3890]	00007FF621CC3890	"FlsSetValue"
00007FF621CABD8E	lea r9,qword ptr ds:[7FF621CC38A8]	00007FF621CC38A8	"InitializeCriticalSectionEx"
00007FF621CABDA1	lea rdx,qword ptr ds:[7FF621CC38A8]	00007FF621CC38A8	"InitializeCriticalSectionEx"
00007FF621CACA37	lea rbx,qword ptr ds:[7FF621CD1A70]	00007FF621CD1A70	"C:\\Users\\david\\Desktop\\crackmes.one\\Biglsim04 - puzzle\\binary\\puzzle.exe"
00007FF621CACA4E	mov rsi,qword ptr ds:[7FF621CD1BD0]	00007FF621CD1BD0	&"\"C:\\Users\\david\\Desktop\\crackmes.one\\Biglsim04 - puzzle\\binary\\puzzle.exe\""
00007FF621CACA55	mov qword ptr ds:[7FF621CD1BB0],rbx	00007FF621CD1BB0	&"C:\\Users\\david\\Desktop\\crackmes.one\\Biglsim04 - puzzle\\binary\\puzzle.exe"
00007FF621CAD1CC	lea rdx,qword ptr ds:[7FF621CC3A20]	00007FF621CC3A20	L"mscoree.dll"
00007FF621CAD1E4	lea rdx,qword ptr ds:[7FF621CC3A38]	00007FF621CC3A38	"CorExitProcess"
00007FF621CAD2DA	mov qword ptr ds:[7FF621CD1BD0],rax	00007FF621CD1BD0	&"\"C:\\Users\\david\\Desktop\\crackmes.one\\Biglsim04 - puzzle\\binary\\puzzle.exe\""
00007FF621CAD2E7	mov qword ptr ds:[7FF621CD1BD8],rax	00007FF621CD1BD8	&L"\"C:\\Users\\david\\Desktop\\crackmes.one\\Biglsim04 - puzzle\\binary\\puzzle.exe\""
00007FF621CAD867	lea rdx,qword ptr ds:[7FF621CC3C00]	00007FF621CC3C00	L"_.,"
00007FF621CADFD9	mov r9,qword ptr ds:[7FF621CC3AE8]	00007FF621CC3AE8	&L"LC_COLLATE"
00007FF621CAE002	lea rbp,qword ptr ds:[7FF621CC3AE8]	00007FF621CC3AE8	&L"LC_COLLATE"
00007FF621CAE07E	lea rax,qword ptr ds:[7FF621CC3B48]	00007FF621CC3B48	&L"LC_TIME"
00007FF621CAE1E2	lea rdx,qword ptr ds:[7FF621CC3BE0]	00007FF621CC3BE0	L"=;"
00007FF621CAE21C	lea r15,qword ptr ds:[7FF621CC3AE8]	00007FF621CC3AE8	&L"LC_COLLATE"
00007FF621CAE24E	lea rax,qword ptr ds:[7FF621CC3B48]	00007FF621CC3B48	&L"LC_TIME"
00007FF621CAE7B6	lea rdx,qword ptr ds:[7FF621CC3BF0]	00007FF621CC3BF0	L"-_."
00007FF621CB4914	mov rax,qword ptr ds:[7FF621CC4D58]	00007FF621CC4D58	&L"zh-TW"
00007FF621CB491D	mov rax,qword ptr ds:[7FF621CC4D50]	00007FF621CC4D50	&L"ko-KR"
00007FF621CB4926	mov rax,qword ptr ds:[7FF621CC4D48]	00007FF621CC4D48	&L"zh-CN"
00007FF621CB492F	mov rax,qword ptr ds:[7FF621CC4D40]	00007FF621CC4D40	&L"ja-JP"
00007FF621CB49FC	mov rbx,qword ptr ds:[7FF621CC4D58]	00007FF621CC4D58	&L"zh-TW"
00007FF621CB4A05	mov rbx,qword ptr ds:[7FF621CC4D50]	00007FF621CC4D50	&L"ko-KR"
00007FF621CB4A0E	mov rbx,qword ptr ds:[7FF621CC4D48]	00007FF621CC4D48	&L"zh-CN"
00007FF621CB4A17	mov rbx,qword ptr ds:[7FF621CC4D40]	00007FF621CC4D40	&L"ja-JP"
00007FF621CB6385	lea rbx,qword ptr ds:[7FF621CC46C0]	00007FF621CC46C0	&"Sun"
00007FF621CB6945	lea rax,qword ptr ds:[7FF621CC46C0]	00007FF621CC46C0	&"Sun"
00007FF621CB6972	lea rax,qword ptr ds:[7FF621CC46C0]	00007FF621CC46C0	&"Sun"
00007FF621CB69A5	lea rax,qword ptr ds:[7FF621CC46C0]	00007FF621CC46C0	&"Sun"

```
00007FF621CB715D  lea rdx,qword ptr ds:[7FF621CC5D58]   00007FF621CC5D58  L"ACP"
00007FF621CB716D  lea rdx,qword ptr ds:[7FF621CC5D48]   00007FF621CC5D48  L"utf8"
00007FF621CB7180  lea rdx,qword ptr ds:[7FF621CC5D60]   00007FF621CC5D60  L"utf-8"
00007FF621CB7193  lea rdx,qword ptr ds:[7FF621CC5D70]   00007FF621CC5D70  L"OCP"
00007FF621CB736B  lea rcx,qword ptr ds:[7FF621CC51C0]   00007FF621CC51C0  &L"america"
00007FF621CB73A4  lea rcx,qword ptr ds:[7FF621CC4DA0]   00007FF621CC4DA0  &L"american"
00007FF621CB7511  lea r8,qword ptr ds:[7FF621CC5D48]    00007FF621CC5D48  L"utf8"
00007FF621CB7B8D  lea rdx,qword ptr ds:[7FF621CC5D58]   00007FF621CC5D58  L"ACP"
00007FF621CB7B9D  lea rdx,qword ptr ds:[7FF621CC5D70]   00007FF621CC5D70  L"OCP"
00007FF621CB7DD7  lea rcx,qword ptr ds:[7FF621CC51C0]   00007FF621CC51C0  &L"america"
00007FF621CB7E3A  lea rcx,qword ptr ds:[7FF621CC4DA0]   00007FF621CC4DA0  &L"american"
00007FF621CB8069  lea r9,qword ptr ds:[7FF621CC6398]    00007FF621CC6398  "CompareStringEx"
00007FF621CB807C  lea rdx,qword ptr ds:[7FF621CC6398]   00007FF621CC6398  "CompareStringEx"
00007FF621CB811B  lea rdx,qword ptr ds:[7FF621CC3838]   00007FF621CC3838  L"api-ms-"
00007FF621CB812E  lea rdx,qword ptr ds:[7FF621CC6368]   00007FF621CC6368  L"ext-ms-"
00007FF621CB8257  lea r9,qword ptr ds:[7FF621CC64C8]    00007FF621CC64C8  "AppPolicyGetProcessTerminationMethod"
00007FF621CB8265  lea rdx,qword ptr ds:[7FF621CC64C8]   00007FF621CC64C8  "AppPolicyGetProcessTerminationMethod"
00007FF621CB82BE  lea rdx,qword ptr ds:[7FF621CC6380]   00007FF621CC6380  "AreFileApisANSI"
00007FF621CB83D6  lea r9,qword ptr ds:[7FF621CC63B0]    00007FF621CC63B0  "EnumSystemLocalesEx"
00007FF621CB83E4  lea rdx,qword ptr ds:[7FF621CC63B0]   00007FF621CC63B0  "EnumSystemLocalesEx"
00007FF621CB84A9  lea r9,qword ptr ds:[7FF621CC6400]    00007FF621CC6400  "GetLocaleInfoEx"
00007FF621CB84B7  lea rdx,qword ptr ds:[7FF621CC6400]   00007FF621CC6400  "GetLocaleInfoEx"
00007FF621CB852D  lea r9,qword ptr ds:[7FF621CC6430]    00007FF621CC6430  "GetUserDefaultLocaleName"
00007FF621CB853B  lea rdx,qword ptr ds:[7FF621CC6430]   00007FF621CC6430  "GetUserDefaultLocaleName"
00007FF621CB859F  lea r9,qword ptr ds:[7FF621CC6458]    00007FF621CC6458  "IsValidLocaleName"
00007FF621CB85AD  lea rdx,qword ptr ds:[7FF621CC6458]   00007FF621CC6458  "IsValidLocaleName"
00007FF621CB861D  lea r9,qword ptr ds:[7FF621CC6490]    00007FF621CC6490  "LCIDToLocaleName"
00007FF621CB862B  lea rdx,qword ptr ds:[7FF621CC6490]   00007FF621CC6490  "LCIDToLocaleName"
00007FF621CB86A5  lea r9,qword ptr ds:[7FF621CC6478]    00007FF621CC6478  "LCMapStringEx"
00007FF621CB86B3  lea rdx,qword ptr ds:[7FF621CC6478]   00007FF621CC6478  "LCMapStringEx"
00007FF621CB8789  lea r9,qword ptr ds:[7FF621CC64B0]    00007FF621CC64B0  "LocaleNameToLCID"
00007FF621CB8797  lea rdx,qword ptr ds:[7FF621CC64B0]   00007FF621CC64B0  "LocaleNameToLCID"
00007FF621CB87ED  lea r9,qword ptr ds:[7FF621CC64F8]    00007FF621CC64F8  "SystemFunction036"
00007FF621CB87FB  lea rdx,qword ptr ds:[7FF621CC64F8]   00007FF621CC64F8  "SystemFunction036"
00007FF621CB8860  lea rdx,qword ptr ds:[7FF621CC6380]   00007FF621CC6380  "AreFileApisANSI"
00007FF621CB887D  lea r9,qword ptr ds:[7FF621CC63B0]    00007FF621CC63B0  "EnumSystemLocalesEx"
00007FF621CB888B  lea rdx,qword ptr ds:[7FF621CC63B0]   00007FF621CC63B0  "EnumSystemLocalesEx"
00007FF621CB88A6  lea r9,qword ptr ds:[7FF621CC63E8]    00007FF621CC63E8  "GetDateFormatEx"
00007FF621CB88B4  lea rdx,qword ptr ds:[7FF621CC63E8]   00007FF621CC63E8  "GetDateFormatEx"
00007FF621CB88CF  lea r9,qword ptr ds:[7FF621CC6400]    00007FF621CC6400  "GetLocaleInfoEx"
00007FF621CB88DD  lea rdx,qword ptr ds:[7FF621CC6400]   00007FF621CC6400  "GetLocaleInfoEx"
00007FF621CB88F8  lea r9,qword ptr ds:[7FF621CC6418]    00007FF621CC6418  "GetTimeFormatEx"
00007FF621CB8906  lea rdx,qword ptr ds:[7FF621CC6418]   00007FF621CC6418  "GetTimeFormatEx"
00007FF621CB8921  lea r9,qword ptr ds:[7FF621CC6430]    00007FF621CC6430  "GetUserDefaultLocaleName"
00007FF621CB892F  lea rdx,qword ptr ds:[7FF621CC6430]   00007FF621CC6430  "GetUserDefaultLocaleName"
00007FF621CB894A  lea r9,qword ptr ds:[7FF621CC6458]    00007FF621CC6458  "IsValidLocaleName"
00007FF621CB8958  lea rdx,qword ptr ds:[7FF621CC6458]   00007FF621CC6458  "IsValidLocaleName"
00007FF621CB8973  lea r9,qword ptr ds:[7FF621CC6478]    00007FF621CC6478  "LCMapStringEx"
00007FF621CB8981  lea rdx,qword ptr ds:[7FF621CC6478]   00007FF621CC6478  "LCMapStringEx"
00007FF621CB899C  lea r9,qword ptr ds:[7FF621CC6490]    00007FF621CC6490  "LCIDToLocaleName"
00007FF621CB89AA  lea rdx,qword ptr ds:[7FF621CC6490]   00007FF621CC6490  "LCIDToLocaleName"
00007FF621CB89C5  lea r9,qword ptr ds:[7FF621CC64B0]    00007FF621CC64B0  "LocaleNameToLCID"
00007FF621CB89D3  lea rdx,qword ptr ds:[7FF621CC64B0]   00007FF621CC64B0  "LocaleNameToLCID"
00007FF621CB8A32  lea r9,qword ptr ds:[7FF621CC63D0]    00007FF621CC63D0  "FlsGetValue2"
00007FF621CB8A40  lea rdx,qword ptr ds:[7FF621CC63D0]   00007FF621CC63D0  "FlsGetValue2"
00007FF621CBD248  lea rax,qword ptr ds:[7FF621CD0C30]   00007FF621CD0C30  &"PST"
00007FF621CBD256  lea rax,qword ptr ds:[7FF621CD0C40]   00007FF621CD0C40  &L"PST"
00007FF621CBED42  lea rcx,qword ptr ds:[7FF621CC9848]   00007FF621CC9848  L"CONOUT$"
00007FF621CBEDF1  lea rcx,qword ptr ds:[7FF621CC9848]   00007FF621CC9848  L"CONOUT$"
00007FF621CC101A  or ch,byte ptr ds:[7FF621CC901C]      00007FF621CC901C  L"-gr"
00007FF621CC104A  or ebp,dword ptr ds:[7FF621CC904C]    00007FF621CC904C  L"-ca"
00007FF621CC107A  or ebp,dword ptr ds:[7FF621CC907C]    00007FF621CC907C  L"-ie"
00007FF621CC10BA  or ebp,dword ptr ds:[7FF621CC90BC]    00007FF621CC90BC  L"-tt"
00007FF621CC112A  or ebp,dword ptr ds:[7FF621CC912C]    00007FF621CC912C  L"-co"
00007FF621CC113A  or ebp,dword ptr ds:[7FF621CC913C]    00007FF621CC913C  L"-cr"
00007FF621CC114A  or ch,byte ptr ds:[7FF621CC914C]      00007FF621CC914C  L"-do"
00007FF621CC115A  or ebp,dword ptr ds:[7FF621CC915C]    00007FF621CC915C  L"-ec"
00007FF621CC11FA  or ebp,dword ptr ds:[7FF621CC91FC]    00007FF621CC91FC  L"-sv"
00007FF621CC121A  or ebp,dword ptr ds:[7FF621CC921C]    00007FF621CC921C  L"-ve"
00007FF621CC123A  or ebp,dword ptr ds:[7FF621CC923C]    00007FF621CC923C  L"-es"
```

That's a lot of references! Utilizing the search functionality at the bottom of the `References` tab will help make searching for the desired string references a breeze.



Nada! Well that's a first for me, never before have I had it where there are zero string references found. Something new is always interesting!

Time to switch to a breakpoint approach.

5.2 Break-it down-point Time

5.2.1 Anti-Debugging Breakpoints

Before I start adding breakpoints trying to trace any flag related logic, I first want to see where and how some of the functions for anti-debugging measures are being used.

Function	Reason for Interest
`IsDebuggerPresent`	The simplest direct debugger check; breaking here often shows the exact branch that decides the *good* vs *bad* branch paths.
`SetUnhandledExceptionFilter`	Programs use this to install custom crash/exception handling; it's commonly part of exception-based anti-debug tricks.
`UnhandledExceptionFilter`	Often hit when the program deliberately triggers an exception; breaking here helps you see whether the exception flow is being used as a debugger test.
`RaiseException`	A strong indicator of intentional exception-based detection; it usually marks the start of an anti-debug probe.
`QueryPerformanceCounter`	Used for high-resolution timing checks; stepping/breakpoints can cause delays that the program detects.
`GetTickCount`, `GetTickCount64`	Lower-resolution timing checks; still commonly used to detect "debugger slowdowns" around sensitive code blocks.

Function	Reason for Interest
`VirtualProtect`	Frequently used for unpacking or self-modifying anti-debug stubs; breaking here can lead you to the real code being revealed or patched in memory.
`GetProcAddress`	Shows when the binary dynamically resolves hidden anti-debug APIs (often from `ntdll`); the requested function name is a big giveaway.
`LoadLibraryExW`	Often paired with `GetProcAddress` to pull in `ntdll` / `user32` at runtime; breaking here can expose the moment advanced anti-debug tooling gets loaded.

For those that are following along, here is an *x64dbg* command to add all these breakpoints:

```
bp kernel32.IsDebuggerPresent; bp kernel32.SetUnhandledExceptionFilter; bp
kernel32.UnhandledExceptionFilter; bp kernel32.RaiseException; bp
kernel32.QueryPerformanceCounter;  bp kernel32.GetTickCount;  bp
kernel32.GetTickCount64;  bp kernel32.VirtualProtect;  bp
kernel32.GetProcAddress;  bp kernel32.LoadLibraryExW
```

See Anti-Debugging Breakpoints for a more detailed breakpoint breakdown and logic tracing.

5.2.2 Input Breakpoints

After, I decide to start with breakpoints that might be used for obtaining the user input from the console;

Function	Reason for Interest
`ReadConsoleA/W`	Catches direct keyboard input from the console,can see exactly where the program reads the name/serial and what buffer it lands in.
`WriteConsoleA/W`	Hits when the program prints prompts or messages; stepping right after often leads straight into the input and validation flow.
`ReadFile`	Many console apps read `STDIN` via a handle as if it were a file, so this is a reliable fallback when `ReadConsoleA/W` isn't used.
`WriteFile`	Console output is sometimes routed through file-style writes, so it helps catch prompts and trace the execution path around user interaction.
`GetStdHandle`	Usually called right before `ReadConsoleA/W` / `ReadFile` or output calls, so it's a great "early warning" breakpoint for the I/O path.
`GetCommandLineA/W`	Useful when input is passed as command-line args; you can see raw input early before it gets parsed or transformed. Doesn't seem necessary for this *PE* as it doesn't appear to use command line arguements, although it does not hurt to add it.
`GetProcAddress`	Reveals dynamically resolved APIs (often hidden checks or *CRT* - C Runtime - calls); the requested function name can instantly expose the program's real strategy.

For those that are following along, here is an *x64dbg* command to add all these breakpoints:

```
bp kernel32.ReadConsoleW; bp kernel32.ReadConsoleA; bp kernel32.WriteConsoleW; bp kernel32.WriteConsoleA; bp kernel32.ReadFile; bp kernel32.WriteFile; bp kernel32.GetStdHandle; bp kernel32.GetCommandLineA; bp kernel32.GetCommandLineW; bp kernel32.GetProcAddress
```

See Input Breakpoints for a more detailed breakpoint breakdown and logic tracing.

---

6. Dynamic Analysis - Tracing Breakpoints and Stepping Over Logic

See Windows x64 Calling Convention for a quick refresher on Windows x64 calling convention.

6.1 Anti-Debugging Breakpoints

With the new breakpoints added, I resume program execution from the entry breakpoint.

Address	Module/Label/Exception	State	Disassembly	Hits
00007FFDA1B72B00	<kernel32.dll.GetTickCount64>	Enabled	mov ecx,dword ptr ds:[7FFE0004]	1
00007FFDA1B78600	<kernel32.dll.GetTickCount>	Disabled	mov ecx,7FFE0320	27
00007FFDA1B83FB0	<kernel32.dll.QueryPerformanceCounter>	Enabled	jmp qword ptr ds:[<QueryPerformanceCounter>]	0
00007FFDA1B93C70	<kernel32.dll.GetProcAddress>	Enabled	mov r8,qword ptr ss:[rsp]	17
00007FFDA1B982B0	<kernel32.dll.VirtualProtect>	Enabled	jmp qword ptr ds:[<VirtualProtect>]	27
00007FFDA1B9B110	<kernel32.dll.RaiseException>	Enabled	jmp qword ptr ds:[<RaiseException>]	0
00007FFDA1B9C600	<kernel32.dll.LoadLibraryExW>	Enabled	jmp qword ptr ds:[<LoadLibraryExW>]	9
00007FFDA1B9D9A0	<kernel32.dll.IsDebuggerPresent>	Enabled	jmp qword ptr ds:[<IsDebuggerPresent>]	0
00007FFDA1BA3600	<kernel32.dll.SetUnhandledExceptionFilter>	Enabled	jmp qword ptr ds:[<SetUnhandledExceptionFilter>]	1
00007FFDA1BBBE60	<kernel32.dll.UnhandledExceptionFilter>	Enabled	jmp qword ptr ds:[<UnhandledExceptionFilter>]	0

I disabled the `GetTickCount` breakpoint as it was getting triggered on each frame, instead replacing it with a breakpoint in the caller that I hope will bring me closer to the flag comparison logic.

There seems to be more going on than a simple console checker. `GetProcAddress` (x17) + `LoadLibraryExW` (x9) on start-up shows that the binary is *OR* might-be keeping the static import table small/boring and resolving lots of APIs at runtime.

I also noticed that `IsDebuggerPresent` breakpoint never gets triggered, even upon input validation.

6.1.1 kernel32.dll.LoadLibraryExW

See LoadLibraryExW Function Definition for function definition details.

Switching over to the *Call Stack* tab I can see that it is being directly called by the *PE*. This means that the target binary is the one actually making the call to `LoadLibraryExW` and not some other module/code.

Address	To	From	Size	Party	Comment
000000B6B374F908	00007FF621CABB8B	00007FFC2D0BC600	8	User	kernel32.LoadLibraryExW
000000B6B374F910	0000000000000000	00007FF621CABB8B		User	puzzle.00007FF621CABB8B

Continuing the execution into `KERNEL32.DLL.LoadLibraryExW` I see that the following registers have the values:

- **Call #1** - Most likely *normal OS dependency resolution* with a *safe flag* restricting search to *System32*.

Register	Value	Note
RCX	00007FF685B937E0	L"api-ms-win-core-synch-l1-2-0"
RDX	0000000000000000	
R8	0000000000000800	`LOAD_LIBRARY_SEARCH_SYSTEM32` = 0x00000800

- **Call #2** - Most likely *normal OS dependency resolution* with a *safe flag* restricting search to *System32*.

Register	Value	Note
RCX	00007FF685B937A0	L"api-ms-win-core-fibers-l1-1-1"
RDX	0000000000000000	
R8	0000000000000800	`LOAD_LIBRARY_SEARCH_SYSTEM32` = 0x00000800

- **Call #3** - Most likely *normal OS dependency resolution* with a *safe flag* restricting search to *System32*.

Register	Value	Note
RCX	00007FF685B95E90	L"api-ms-win-core-fibers-l1-1-2"
RDX	0000000000000000	
R8	0000000000000800	`LOAD_LIBRARY_SEARCH_SYSTEM32` = 0x00000800

- **Call #4** - Most likely *normal OS dependency resolution* with a *safe flag* restricting search to *System32*.

Register	Value	Note
RCX	00007FF685B95F80	L"api-ms-win-core-localization-l1-2-1"
RDX	0000000000000000	
R8	0000000000000800	`LOAD_LIBRARY_SEARCH_SYSTEM32` = 0x00000800

- **Call #5** - Likely normal runtime/loader behaviour.

Register	Value	Note
RCX	00007FF685B93820	L"kernel32"
RDX	0000000000000000	
R8	0000000000000800	`LOAD_LIBRARY_SEARCH_SYSTEM32` = 0x00000800

- **Call #6** - Most likely *normal OS dependency resolution* with a *safe flag* restricting search to *System32*.

Register	Value	Note
RCX	00007FF685B96080	L"api-ms-win-core-string-l1-1-0"

Register	Value	Note
RDX	0000000000000000	
R8	0000000000000800	`LOAD_LIBRARY_SEARCH_SYSTEM32` = 0x00000800

- **Call #7** - Most likely *normal OS dependency resolution* with a *safe flag* restricting search to *System32*.

Register	Value	Note
RCX	00007FF685B95E50	L"api-ms-win-core-datetime-l1-1-1"
RDX	0000000000000000	
R8	0000000000000800	`LOAD_LIBRARY_SEARCH_SYSTEM32` = 0x00000800

- **Call #8** - Most likely *normal OS dependency resolution* with a *safe flag* restricting search to *System32*.

Register	Value	Note
RCX	00007FF685B95FD0	L"api-ms-win-core-localization-obsolete-l1-2-0"
RDX	0000000000000000	
R8	0000000000000800	`LOAD_LIBRARY_SEARCH_SYSTEM32` = 0x00000800

- **Call #9** - Most likely *normal OS dependency resolution* with a *safe flag* restricting search to *System32*.

Register	Value	Note
RCX	00007FF685B961D0	L"api-ms-win-security-systemfunctions-l1-1-0"

Register	Value	Note
RDX	0000000000000000	
R8	0000000000000800	`LOAD_LIBRARY_SEARCH_SYSTEM32` = 0x00000800

The binary consistently restricts DLL search to *System32* during early initialization which aligns with modern safe-loading practices and reduces the likelihood of DLL search-order hijacking. The `api-ms-win-*` entries reflect Windows API-set indirection. Their presence here is typical for modern *MSVC* builds and does not by itself indicate obfuscation. None of the observed `LoadLibraryExW` function calls directly load `ntdll.dll` or other modules - `user32.dll`, `dbghelp.dll` - commonly associated with advanced anti-debug checks. The initial loads appear consistent with baseline OS/runtime dependencies.

6.1.2 kernel32.dll.SetUnhandledExceptionFilter

See SetUnhandledExceptionFilter Function Definition for function definition details.

Return value is `NULL` (*0x00000000*), indicating no prior top-level exception filter was registered before this call. Nothing interesting happening here, so I continue on to the next breakpoint.

6.1.3 kernerl32.dll.GetTickCount64

See GetTickCount64 Function Definition for function definition details.

Since `GetTickCount64` is only called once I decide to investigate what it's being used for. Upon hitting the breakpoint, I hit Debug - Execute till return (*CTRL + F9*) and get to the caller. Alternatively, using the *Call Stack* would bring me to the same location by clicking on the frame underneath the `GetTickCount64` frame.

My first guess without diving too deep into this function is that it might be generating some kind of value from the system time. This value could then be used as an encoding seed of sorts (***just a guess***).

```
00007FF685B71080    48:83EC 28          sub rsp,28
00007FF685B71084    0F31                rdtsc
00007FF685B71086    48:C1E2 20          shl rdx,20
00007FF685B7108A    48:0BC2             or rax,rdx
00007FF685B7108D    48:894424 38        mov qword ptr ss:[rsp+38],rax
00007FF685B71092    FF15 68FF0100       call qword ptr ds:[<GetTickCount64> ]
00007FF685B71098    48:894424 40        mov qword ptr ss:[rsp+40],rax
00007FF685B7109D    48:8D4424 38        lea rax,qword ptr ss:[rsp+38]
00007FF685B710A2    48:894424 30        mov qword ptr ss:[rsp+30],rax
00007FF685B710A7    48:8B4424 40        mov rax,qword ptr ss:[rsp+40]
00007FF685B710AC    4C:8B4424 30        mov r8,qword ptr ss:[rsp+30]
00007FF685B710B1    48:8B4424 30        mov rax,qword ptr ss:[rsp+30]
00007FF685B710B6    48:8B5424 38        mov rdx,qword ptr ss:[rsp+38]
00007FF685B710BB    0FB6C8              movzx ecx,al
00007FF685B710BE    6BC1 3B             imul eax,ecx,3B
00007FF685B710C1    B9 A7000000         mov ecx,A7
00007FF685B710C6    49:C1E8 07          shr r8,7
00007FF685B710CA    41:32D0             xor dl,r8b
00007FF685B710CD    32D0                xor dl,al
00007FF685B710CF    0FB6C2              movzx eax,dl
00007FF685B710D2    0F45C8              cmovne ecx,eax
00007FF685B710D5    884C24 30           mov byte ptr ss:[rsp+30],cl
00007FF685B710D9    0FB64424 30         movzx eax,byte ptr ss:[rsp+30]
00007FF685B710DE    8805 80210300       mov byte ptr ds:[7FF685BA3264 ],al
00007FF685B710E4    C64424 30 00        mov byte ptr ss:[rsp+30],0
00007FF685B710E9    48:83C4 28          add rsp,28
00007FF685B710ED    C3                  ret
```

An interesting instruction I notice is `rdtsc` which reads the CPU's *Time Stamp Counter* (*TSC*). The return is a *64-bit number* that usually increases constantly whilst the system runs. After the instruction, `EAX` holds the *low 32-bits* and `EDX` holds the *high 32-bits*. These are then usually combined by an `or` instruction.

```
rdtsc                read time stamp counter
shl rdx,20           shift high 32-bits into upper half of RDX
or rax,rdx           combine low and high bits into 64-bit TSC value in RAX
```

It also appears to be doing some kind of encoding and transformation based off the return values from `rdtsc` and `GetTickCount64`.

After spending some time decoding each instruction it does indeed seem like it creates some kind of seed value and stores it within a global.

```
sub rsp,28                                  Seeding function based on system time?
rdtsc                                       read time stamp counter
shl rdx,20                                  shift high 32-bits into upper half of RDX
or rax,rdx                                  combine low and high bits into 64-bit TSC value in RAX
mov qword ptr ss:[rsp+38],rax               save TSC to local var RSP+38
call qword ptr ds:[<GetTickCount64> ]       call kernel32.dll.GetTickCount64 - get ms since boot
mov qword ptr ss:[rsp+40],rax               save GetTickCount64 return value to local var RSP+40
lea rax,qword ptr ss:[rsp+38]               load TSC into RAX
mov qword ptr ss:[rsp+30],rax               save pointer to local TSC to local var RSP+30
mov rax,qword ptr ss:[rsp+40]               load GetTickCount64 return value into RAX
mov r8,qword ptr ss:[rsp+30]                load pointer to local TSC into R8 register
mov rax,qword ptr ss:[rsp+30]               load pointer to local TSC into RAX register
mov rdx,qword ptr ss:[rsp+38]               load TSC into RDX register
movzx ecx,al                                ECX = lower 8 bits of RAX (TSC pointer) - zero extended
imul eax,ecx,3B                             EAX = ECX (lower 8 bits of TSC pointer) * 0x3B
mov ecx,A7                                  load constant 0xA7 into ECX register
shr r8,7                                    shift right R8 (pointer to local TSC) 0x7
xor dl,r8b                                  xor lower 8 bits of RDX (TSC) by R8 (pointer to local TSC)
xor dl,al                                   xor lower 8 bits of RDX (transformed TSC) by lower 8 bits of RAX (imul result)
movzx eax,dl                                EAX = xor result - zero extended
cmovne ecx,eax                              move EAX into ECX if XOR result is non-zero
mov byte ptr ss:[rsp+30],cl                 move lower 8 bits of RCX into local var RSP+30
movzx eax,byte ptr ss:[rsp+30]              EAX = local var RSP+30 - zero extended
mov byte ptr ds:[7FF685BA3264 ],al          move lower 8-bits (1 byte) of RAX into global
mov byte ptr ss:[rsp+30],0                  move 0 into local var RSP+30
add rsp,28                                  deallocate 0x28 bytes of allocated memory
ret
```

Seems like progress. I added a breakpoint of the instruction `mov byte ptr ds:[7FF865BA3264], al` to keep track of the seed on subsequent executions and proceeded to the return, which lands me in another function.

```
48:3BCA            cmp rcx,rdx
74 30              je puzzle.7FF685B7CF65
48:895C24 08       mov qword ptr ss:[rsp+8],rbx
57                 push rdi
48:83EC 20         sub rsp,20
48:8BFA            mov rdi,rdx
48:8BD9            mov rbx,rcx
48:8B03            mov rax,qword ptr ds:[rbx]
48:85C0            test rax,rax
74 05              je puzzle.7FF685B7CF52
E8 FE270100        call puzzle.7FF685B8F750
48:83C3 08         add rbx,8
48:3BDF            cmp rbx,rdi
75 EA              jne puzzle.7FF685B7CF45
48:8B5C24 30       mov rbx,qword ptr ss:[rsp+30]
48:83C4 20         add rsp,20
5F                 pop rdi
C3                 ret
```

This function appears to loop until `RBX == RDI`, at which point it calls the seeding function that uses `GetTickCount64`. What exactly `RDI` is I am unaware of.

6.1.4 Switching my approach

I'm starting to think that a lot of functions might have been imported and never used *OR* just imported as red-herrings. This has caused me to search in unnecessary areas trying to track down any anti-debugging logic instead of focusing on finding the flag. I will switch gears to attempt to find the flag and see if I trip up any anti-debug code along the way.

6.2 Input Breakpoints

Two of the breakpoints that end up producing interesting results are `WriteFile` and `ReadFile`. There seems to be some kind of loop that iteratively prints `Hello World!\nEnter password:`. This would explain why I was unable to find any string references ix *x64dbg*, as it seems to be dynamically loading and printing the value. This doesn't seem an avenue worth exploring as it just handles the output to console. Taking note of this, I continue to where the user input is captured as I feel that would achieve more desirable results.

6.2.1 kernel32.dll.WriteFile

After stepping around I land on an interesting function.

```
8BC8                    mov ecx,eax
83F8 0A                 cmp eax,A
74 36                   je puzzle.7FF685B72840
48:8D45 F7              lea rax,qword ptr ss:[rbp-9]
BB 01000000             mov ebx,1
48:2BD8                 sub rbx,rax
48:8D7D F7              lea rdi,qword ptr ss:[rbp-9]
66:0F1F4400 00          nop word ptr ds:[rax+rax],ax
83F9 FF                 cmp ecx,FFFFFFFF
74 1B                   je puzzle.7FF685B72840
48:8D043B               lea rax,qword ptr ds:[rbx+rdi]
48:83F8 40              cmp rax,40
73 05                   jae puzzle.7FF685B72834
880F                    mov byte ptr ds:[rdi],cl
48:FFC7                 inc rdi
E8 37980000             call puzzle.7FF685B7C070
8BC8                    mov ecx,eax
83F8 0A                 cmp eax,A
75 E0                   jne puzzle.7FF685B72820
0FB645 F7               movzx eax,byte ptr ss:[rbp-9]
33C9                    xor ecx,ecx
48:8B9C24 18010000      mov rbx,qword ptr ss:[rsp+118]
84C0                    test al,al
74 55                   je puzzle.7FF685B728A7
48:83F9 40              cmp rcx,40
73 0C                   jae puzzle.7FF685B72864
0FB6440D F8             movzx eax,byte ptr ss:[rbp+rcx-8]
48:FFC1                 inc rcx
84C0                    test al,al
75 EE                   jne puzzle.7FF685B72852
48:83F9 09              cmp rcx,9
75 3D                   jne puzzle.7FF685B728A7
33D2                    xor edx,edx
48:8D3D DD8C0200        lea rdi,qword ptr ds:[7FF685B9B550 ]
0F1F40 00               nop dword ptr ds:[rax],eax
66:0F1F8400 00000000    nop word ptr ds:[rax+rax],ax
0FB6043A                movzx eax,byte ptr ds:[rdx+rdi]
34 9F                   xor al,9F
8845 67                 mov byte ptr ss:[rbp+67],al
0FB64C15 F7             movzx ecx,byte ptr ss:[rbp+rdx-9]
0FB645 67               movzx eax,byte ptr ss:[rbp+67]
C645 67 00              mov byte ptr ss:[rbp+67],0
3AC8                    cmp cl,al
75 0D                   jne puzzle.7FF685B728A7
48:FFC2                 inc rdx
48:83FA 09              cmp rdx,9
72 DD                   jb puzzle.7FF685B72880
B2 01                   mov dl,1
EB 02                   jmp puzzle.7FF685B728A9
32D2                    xor dl,dl
33C0                    xor eax,eax
48:8D7D F7              lea rdi,qword ptr ss:[rbp-9]
B9 40000000             mov ecx,40
F3:AA                   rep stosb
B0 DE                   mov al,DE
84D2                    test dl,dl
74 3C                   je puzzle.7FF685B728F8
C745 9F DEFCFCFA        mov dword ptr ss:[rbp-61],FAFCFCDE
48:8D7D 9F              lea rdi,qword ptr ss:[rbp-61]
C745 A3 ECECBFD8        mov dword ptr ss:[rbp-5D],D8BFECEC
C745 A7 EDFEF1EB        mov dword ptr ss:[rbp-59],EBF1FEED
C745 AB FAFBBE95        mov dword ptr ss:[rbp-55],95BEFBFA
C645 AF 9F              mov byte ptr ss:[rbp-51],9F
```

The first immediate thing that stands out to me is the repeated loops to an index amount of `0x40`.

The two loops at the start take some time but eventually click for me. The first loop I found just takes the user input up until a newline character and then checks if the result is 9 characters long.

```
cmp ecx,FFFFFFFF                         loop until 0xFFFFFFFF (probably a while loop?)
je puzzle.7FF685B72840                   encoding / checking loop?
lea rax,qword ptr  ds:[rbx+rdi]
cmp rax,40                               loop 0x40 times max
jae puzzle.7FF685B72834
mov byte ptr  ds:[rdi],cl
inc rdi                                  increment loop index
call puzzle.7FF685B7C070                 get next character?
mov ecx,eax
cmp eax,A                                loop until we find 0xA in the user input - loop til newline character
jne puzzle.7FF685B72820
movzx  eax,byte ptr  ss:[rbp-9]
xor ecx,ecx
mov rbx,qword ptr  ss:[rsp+118]          [rsp+118]:&"C:\\Users\\david\\Desktop\\crackmes.one\\Biglsim04 - puzzl
test al,al                               empty check on user input?
je puzzle.7FF685B728A7                   jump if empty user input
cmp rcx,40                               loop 0x40 times max
jae puzzle.7FF685B72864
movzx  eax,byte ptr  ss:[rbp+rcx-8]
inc rcx                                  increment loop index
test al,al
jne puzzle.7FF685B72852                  loop until string delimiter
cmp rcx,9                                09:'\t'
jne puzzle.7FF685B728A7                  jump if string is not 0x9 characters long
```

Continuing the execution, I get to the loop that prints "*Access Denied*" onto the screen.

```
mov  dword ptr  ss:[rsp+20],FAFCFCDE
lea rdi,qword ptr  ss:[rsp+20]
mov  dword ptr  ss:[rsp+24],DBBFECEC
mov  dword ptr  ss:[rsp+28],FAF6F1FA
mov  dword ptr  ss:[rbp-7D],9F95BEFB
nop  dword ptr  ds:[rax],eax
xor  al,9F                               [L2] print "Access Denied" loop
movzx  edx,al
call  puzzle.7FF685B73280
movzx  eax,byte ptr  ds:[rdi+1]
lea rdi,qword ptr  ds:[rdi+1]
cmp  al,9F
jne  puzzle.7FF685B72920                 [L2] loop end
```

Above it, I notice a similar looking loop. Considering the conditional before it, I assume that it is the "*Access Allowed*" branch.

```
test  dl,dl
je  puzzle.7FF685B728F8                  jump over "Access Allowed" printing loop
mov  dword ptr  ss:[rbp-61],FAFCFCDE
lea  rdi,qword ptr  ss:[rbp-61]          [rbp-61]:SystemFunction036+D
mov  dword ptr  ss:[rbp-5D],D8BFECEC
mov  dword ptr  ss:[rbp-59],EBF1FEED
mov  dword ptr  ss:[rbp-55],95BEFBFA
mov  byte ptr  ss:[rbp-51],9F
xor  al,9F                               [L1] "Access Allowed" loop?
movzx  edx,al
call  puzzle.7FF685B73280
movzx  eax,byte ptr  ds:[rdi+1]
lea  rdi,qword ptr  ds:[rdi+1]
cmp  al,9F
jne  puzzle.7FF685B728E0                 [L1] loop end
jmp  puzzle.7FF685B72936                 jump over "Access Denied" printing loop
mov  dword ptr  ss:[rsp+20],FAFCFCDE
lea  rdi,qword ptr  ss:[rsp+20]
mov  dword ptr  ss:[rsp+24],DBBFECEC
mov  dword ptr  ss:[rsp+28],FAF6F1FA
mov  dword ptr  ss:[rbp-7D],9F95BEFB
nop  dword ptr  ds:[rax],eax
xor  al,9F                               [L2] print "Access Denied" loop
movzx  edx,al
call  puzzle.7FF685B73280
movzx  eax,byte ptr  ds:[rdi+1]
lea  rdi,qword ptr  ds:[rdi+1]
cmp  al,9F
jne  puzzle.7FF685B72920                 [L2] loop end
```

Great, so I - *think I* - have found where the comparison takes place before the right/wrong branches. My next step revolves around setting a breakpoint on that `test dl, dl` and restarting program execution to see what the registers look like.

```
lea rdi,qword ptr ss:[rbp-9]     load the address of the user input into RDI
mov ecx,40                       move 0x40 into ECX for REP instruction following
rep stosb
mov al,DE
test dl,dl
je puzzle.7FF685B728F8           jump over "Access Allowed" printing loop
```

Side note: one thing that I am really starting to notice is the repeated use of the value `0x40`, especially for loops. Breaking at the `test` instruction, it seems that the important logic is not around there but a bit higher.

A bit above there seems to be a loop that checks if the user input is 9 characters long. If it is not 9 characters long, it jumps to the *"Access Denied"* code branch.

```
test al,al                          empty check on user input?
je puzzle.7FF685B728A7              jump if empty user input
cmp rcx,40                          loop 0x40 times max
jae puzzle.7FF685B72864
movzx eax,byte ptr ss:[rbp+rcx-8]
inc rcx                             increment loop index
test al,al
jne puzzle.7FF685B72852             loop until string delimiter
cmp rcx,9                           09:'\t'
jne puzzle.7FF685B728A7             jump if string is not 0x9 characters long
```

Changing my input from `helloworld` to `helloworl` I confirm that it indeed is checking the length of the user input and ensuring it is 9 characters long. With that, I continue into the logic that was being jumped over.

```
75 3D                       jne puzzle.7FF685B728A7              jump if string is not 0x9 characters long
33D2                        xor edx,edx
48:8D3D DD8C0200            lea rdi,qword ptr ds:[7FF685B9B550]
0F1F40 00                   nop dword ptr ds:[rax],eax
66:0F1F8400 00000000        nop word ptr ds:[rax+rax],ax
0FB6043A                    movzx eax,byte ptr ds:[rdx+rdi]
34 9F                       xor al,9F
8845 67                     mov byte ptr ss:[rbp+67],al
0FB64C15 F7                 movzx ecx,byte ptr ss:[rbp+rdx-9]
0FB645 67                   movzx eax,byte ptr ss:[rbp+67]
C645 67 00                  mov byte ptr ss:[rbp+67],0
3AC8                        cmp cl,al
75 0D                       jne puzzle.7FF685B728A7
48:FFC2                     inc rdx
48:83FA 09                  cmp rdx,9                            09:'\t'
72 DD                       jb puzzle.7FF685B72880
B2 01                       mov dl,1
EB 02                       jmp puzzle.7FF685B728A9
32D2                        xor dl,dl
```

And I think I spot the smoking gun.

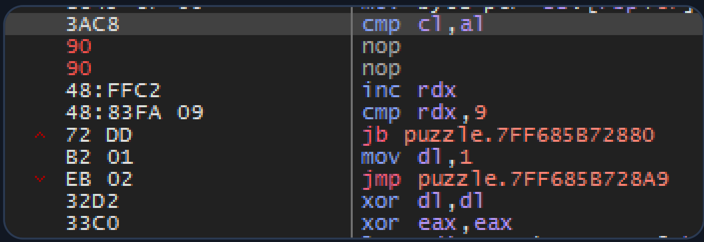
---

7. Validation Path

The actual flag comparison logic!
`RAX` (`AL` is the lower *8-bits* of `RAX`) represents a character from our user input being compared against `RCX` (`CL` is the lower *8-bits* of `RCX`) which I assume is the respective index character of the flag.

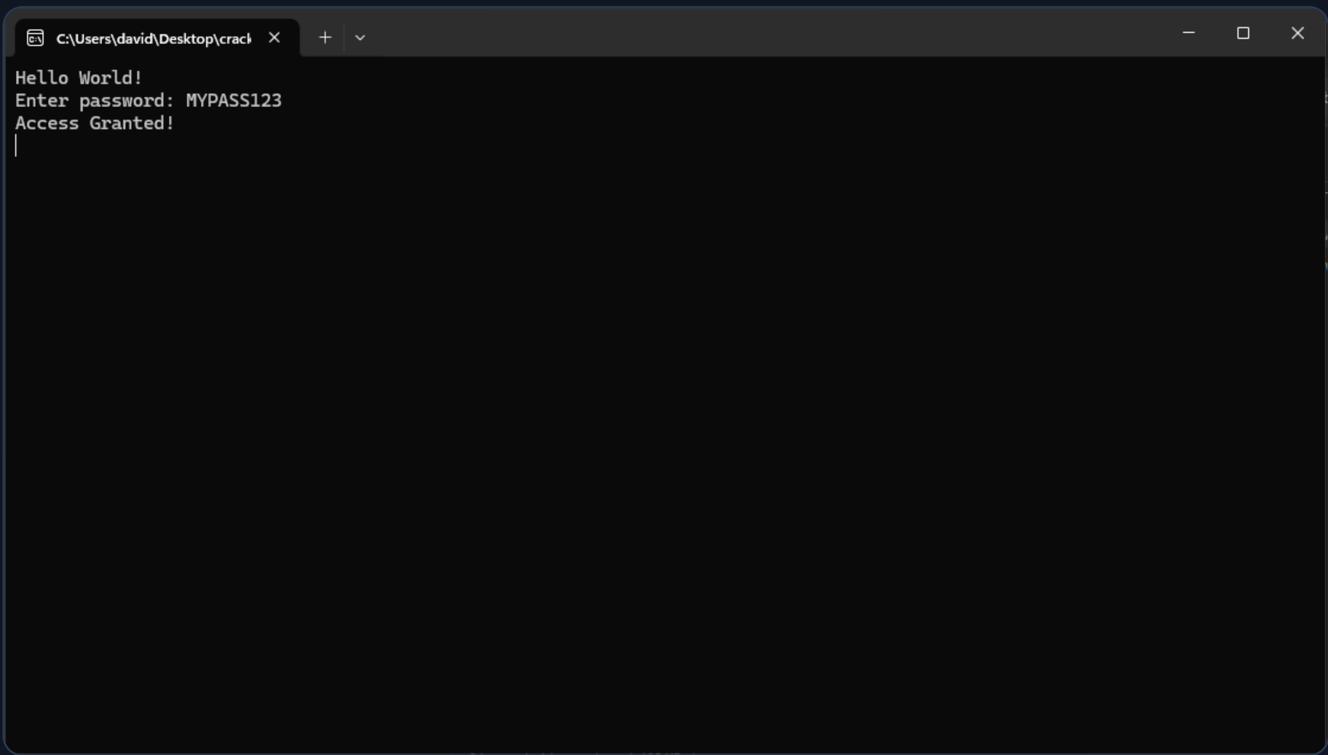
```
00007FF685B72896    3AC8     cmp cl,al
00007FF685B72898    75 0D    jne puzzle.7FF685B728A7
```

Now to just extract the flag characters. Before doing so I temporarily `nop` the `jne` instruction as to not jump to the "*Access Denied*" branch.



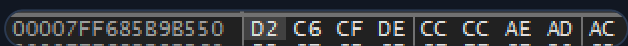
As I continue execution from my breakpoint on the `cmp cl, al` instruction; the `RAX` register spells out: `M`, `Y`, `P`, `A`, `S`, `S`, `1`, `2`, `3`.

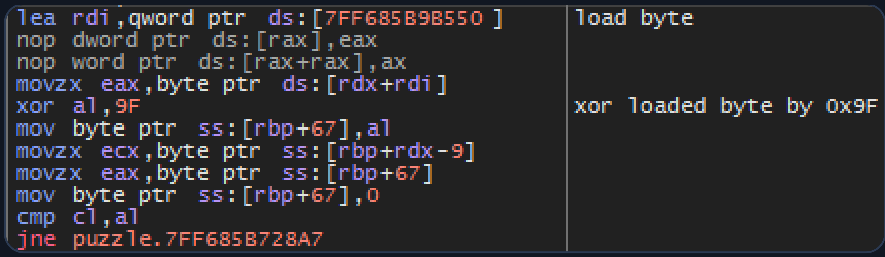
Time to enter the flag `MYPASS123` and see if it is indeed the correct flag.



Great success!

It appears that it is loading in the bytes `D2 C6 CF DE CC CC AE AD AC` one byte at a time and xoring it with `0x9F` to get the flag `MYPASS123`.





```
lea rdi,qword ptr  ds:[7FF685B9B550 ]     load byte
nop dword ptr  ds:[rax],eax
nop word ptr  ds:[rax+rax],ax
movzx  eax,byte ptr  ds:[rdx+rdi]
xor  al,9F                                xor loaded byte by 0x9F
mov  byte ptr  ss:[rbp+67],al
movzx  ecx,byte ptr  ss:[rbp+rdx-9]
movzx  eax,byte ptr  ss:[rbp+67]
mov  byte ptr  ss:[rbp+67],0
cmp  cl,al
jne  puzzle.7FF685B728A7
```

Going back to the "*Access Denied*" and "*Access Granted*" strings I realize it is also doing a `xor` by `0x9F` to decode the strings. I also notice it for the "*Enter password:* " text so I assume that it is doing the same for "*Hello World!*" as well.

Original Bytes	Decoded Bytes (XOR by 0x9F)	ASCII
DE FC FC FA EC EC BF D8 ED FE F1 EB FA FB BE 95	41 63 63 65 73 73 20 47 72 61 6E 74 65 64 21 0A	Access Granted!\n
DE FC FC FA EC EC BF DB FA F1 F6 FA FB BE 95	41 63 63 65 73 73 20 44 65 6E 69 65 64 21 0A	Access Denied!\n
DA F1 EB FA ED BF EF FE EC EC E8 F0 ED FB A5 BF	45 6E 74 65 72 20 70 61 73 73 77 6F 72 64 3A 20	Enter password:

---

8. Useful Notes, Reminders, and Definitions

8.1 Windows x64 Calling Convention

On Windows x64 calling convention:

- RCX = 1st parameter
- RDX = 2nd
- R8 = 3rd
- R9 = 4th
- RAX = return value
- If there are *more than four arguements*, the rest go on the *stack*.

8.1.1 Volatile & Non-Volatile registers

Volatile (caller-saved): `RAX, RCX, RDX, R8-R11`

If you're tracking values across calls, expect volatile regs to get clobbered.

Non-volatile (callee-saved): `RBX, RBP, RSI, RDI, R12-R15`

8.1.2 Shadow Space

The caller *MUST* reserve 32 bytes of *shadow space* on the stack before the call. So even if a function has fewer than 4 parameters, you'll still see that stack layout pattern. It's there so the *callee* has a guaranteed place to spill the first four register arguments if it wants: `RCX`, `RDX`, `R8`, `R9`.

8.1.3 Stack Alignment

Windows x64 requires the stack to be *16-byte aligned at the moment of a* `call`. This is because the `call` instruction pushes an *8-byte* return address, which shifts `RSP` by 8 and can break *16-byte* alignment.

8.2 Function Definitions

8.2.1 kernel32.dll.LoadLibraryExW

`LoadLibraryExW` has three parameters and returns an *HMODULE* (or *NULL* on failure).

```
HMODULE LoadLibraryExW(
  LPCWSTR lpLibFileName,
  HANDLE  hFile,
  DWORD   dwFlags
);
```

1. **lpLibFileName** (`LPCWSTR`)

    - Path or name of the DLL to load.
    - Often something like:
        - `L"kernel32.dll"`
        - `L"C:\\Windows\\System32\\something.dll"`
        - Or an app-local DLL name.
2. **hFile** (`HANDLE`)
    - Usually **NULL**.
    - Historically used for loading from an already-open file handle.
3. **dwFlags** (`DWORD`)
    - Controls *how* the module is loaded / searched.
    - Common ones include:

Flag	Value	Note
	`0x00000000`	Default load behaviour (normal DLL search order).
`DONT_RESOLVE_DLL_REFERENCES`	`0x00000001`	Maps the DLL but *doesn't call* `DllMain` or resolve imports - useful for inspection.
`LOAD_LIBRARY_AS_DATAFILE`	`0x00000002`	Loads the module *as a data file* (resources), not for code execution.
`LOAD_LIBRARY_AS_IMAGE_RESOURCE`	`0x00000020`	Loads *only as an image resource*, mostly for resource access.
`LOAD_LIBRARY_AS_DATAFILE_EXCLUSIVE`	`0x00000040`	Like `AS_DATAFILE` but tries to keep it exclusive so others can't modify it.

Flag	Value	Note
`LOAD_WITH_ALTERED_SEARCH_PATH`	`0x00000008`	Changes search order to prioritize the DLL's directory - older/legacy pattern.
`LOAD_LIBRARY_SEARCH_DLL_LOAD_DIR`	`0x00000100`	Search the directory of the DLL being loaded
`LOAD_LIBRARY_SEARCH_APPLICATION_DIR`	`0x00000200`	Search the executable's directory
`LOAD_LIBRARY_SEARCH_USER_DIRS`	`0x00000400`	Search directories added via `AddDllDirectory`
`LOAD_LIBRARY_SEARCH_SYSTEM32`	`0x00000800`	Search `System32` only
`LOAD_LIBRARY_SEARCH_DEFAULT_DIRS`	`0x00001000`	A safe default set: app directory + system32 + user-added directories (recommended modern choice).

If a weird flag value is present, it may be a *bitwise OR* of multiple flags.

- **Return Value**
  - Success: `HMODULE` for the loaded module.
  - Failure: **NULL** (`RAX = 0`).
    - Then `GetLastError()` can inform you as to why.

Jump Back

8.2.2 kernel32.dll.SetUnhandledExceptionFilter

`SetUnhandledExceptionFilter` accepts one parameter and returns an *LPTOP_LEVEL_EXCEPTION_FILTER* which is the previous unhandled exception filter (or *NULL* if none).

```
LPTOP_LEVEL_EXCEPTION_FILTER SetUnhandledExceptionFilter(
    LPTOP_LEVEL_EXCEPTION_FILTER lpTopLevelExceptionFilter
);
```

1. **lpTopLevelExceptionFilter** (`LPTOP_LEVEL_EXCEPTION_FILTER`)
    - Pointer to a *custom unhandled exception filter* function.
    - This function is called when an exception *isn't handled* by structured exception handling in the process.
    - Often something like:
        - `MyUnhandledExceptionFilter`
        - `NULL` (to clear/disable a previously set filter)

- **Return Value** (`LPTOP_LEVEL_EXCEPTION_FILTER`)
    - Returns a pointer to the *previous* unhandled exception filter.
    - Often:
        - Another filter function pointer if one was already set
        - `NULL` if no previous filter was registered

Jump Back

8.2.3 kernerl32.dll.GetTickCount64

`GetTickCount64` takes no parameters and returns a *ULONGLONG* representing the number of milliseconds that have elapsed since the system was started.

```
ULONGLONG GetTickCount64(
    VOID
);
```

- **Return Value (`ULONGLONG`)**
  - Returns the number of **milliseconds since system boot**.
  - Often used for:
    - timing measurements
    - detecting delays (e.g., anti-debug “single-step slowdown” checks)

Jump Back

8.3 x64 Register Size Cheat Sheet

Each 64-bit register has smaller *views*; Example with `RAX`:

Size	Name	What it is
64-bit	`RAX`	full register
32-bit	`EAX`	low 32 bits of `RAX`
16-bit	`AX`	low 16 bits
8-bit (low)	`AL`	low 8 bits
8-bit (high)	`AH`	bits 8–15 (upper half of `AX`)

So `AX = AH:AL`. The same pattern applies to others

Common Registers; High *8-bit* forms exist only for these classic registers:

64-bit	32-bit	16-bit	8-bit low	8-bit high*
RAX	EAX	AX	AL	AH
RBX	EBX	BX	BL	BH
RCX	ECX	CX	CL	CH

64-bit	32-bit	16-bit	8-bit low	8-bit high*
RDX	EDX	DX	DL	DH

Pointer/Index Registers; These do *NOT* have `AH/BH/CH/DH` style high *8-bit* forms.

64-bit	32-bit	16-bit	8-bit low
RSI	ESI	SI	SIL
RDI	EDI	DI	DIL
RBP	EBP	BP	BPL
RSP	ESP	SP	SPL

Extended registers (x64-only); No high *8-bit* halves here either:

64-bit	32-bit	16-bit	8-bit low
R8	R8D	R8W	R8B
R9	R9D	R9W	R9B
R10	R10D	R10W	R10B
R11	R11D	R11W	R11B
R12	R12D	R12W	R12B
R13	R13D	R13W	R13B
R14	R14D	R14W	R14B
R15	R15D	R15W	R15B

Important note that writing to a *32-bit* register, such as `EAX`, *zeroes* the upper 32 bits of the 64-bit register (`RAX`).

9. Conclusion

This crackme turned out to be a really nice reminder that "*normal-looking*" console binaries can still hide their logic in slightly unusual places without resorting to heavy packing or obfuscation. Static recon showed a clean *PE* layout, reasonable entropy across all sections, and a modern *MSVC* toolchain with only `KERNEL32.dll` imported, which initially made the target look almost too boring. Dynamic analysis quickly disproved that: the program makes heavy use of `LoadLibraryExW` / `GetProcAddress`, dynamically resolves APIs, builds its console strings at runtime, and seeds a global byte using a mix of `RDTSC` and `GetTickCount64` before dropping into the real validation.

From there, following the input path via `WriteFile` / `ReadFile` and watching the repeated `0x40` -bounded loops eventually led to the heart of the puzzle: a length check enforcing a 9-character password and a tight comparison loop where each user byte is XOR-checked against a pre-decoded constant. By neutralizing the failure branch (`nop` -ing the `jne`) and single-stepping through the comparison, the hidden password `MYPASS123` effectively revealed itself one character at a time.

Looking back, the biggest time sink was chasing anti-debug "*ghosts*": a lot of effort went into breakpoints on timing APIs and exception handlers that, in this specific challenge, never materially affected the success path. The lesson is not that those checks are unimportant, but that they should be treated as *supporting evidence* rather than the main objective—especially when the goal is simply to recover the flag.

9.1 Lessons Learned

- **Stay goal-oriented.** It's easy to get lost in potential anti-debug code; keep coming back to "where is input read, where is it validated, and what decides success vs failure?"
- **Let behaviour guide you.** When strings aren't referenced statically, use I/O breakpoints and console behaviour (prompts, error messages) to anchor yourself in the code.
- **Small patterns matter.** Repeated values like `0x40`, recurring loop structures, and consistent register usage are strong hints about array sizes, buffer layouts, and validation loops.

- **Seeds and globals are tell-tales.** A function that mixes `RDTSC` + `GetTickCount64` and stores a byte to a global is almost certainly feeding into later logic—even if it's just cosmetic or a red herring in this challenge.
- **Document as you go.** Writing down calling-convention notes, register cheat sheets, and function definitions along the way made the analysis much easier to follow and will pay off in future crackmes.

Overall, this puzzle was a solid exercise in stepping through real-world *MSVC* output, reading x64 calling convention “in the wild,” and resisting the urge to overcomplicate things when the core validation logic was relatively straightforward once located.