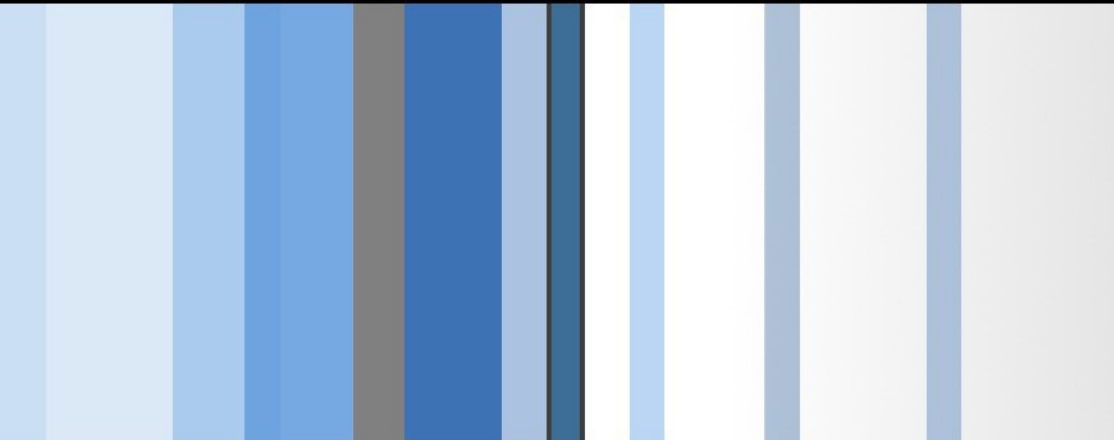


CSC 471 Modern Malware Analysis

Anti-Debugging Techniques (2): Dynamic Anti-Debugging

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Anti-Debugging

- Malware authors have always looked for new techniques to **stay invisible**. This includes, of course, being invisible on the compromised machine, but it is even more important to hide malicious indicators and behavior during analysis.
- **Debugging** is the essential part of malware analysis. Every time we need to drill down into malware behavior, restore encryption methods or examine communication protocols, we use debuggers.
- To make the post-detection analysis more difficult, threat actors use various anti-analysis techniques, one of the more common ones is **Anti-Debugging**.



Static Anti-Debugging VS. Dynamic Anti-Debugging

| | Static | Dynamic |
|-------------------------|---------------------------|--|
| Difficulty Level | Easy, Medium | Hard |
| Key idea | Use System Information | Reverse and exploit Debugger |
| Target | Detect Debugger | Hide it's own code and data |
| Time point | When debugging started | While debugger are running |
| Defend Method(s) | API hook, debugger plugin | API hook, Debugger Plugin, Other tools |
| Example(s) | PEB, TEB, Native API, TLS | SHE, Break Points (INT3), Timing Check |

Dynamic Anti-Debugging

Dynamic Anti-Debugging techniques are trying to interfere with the debugger, so it cannot debug the binary program correctly (to hide its Original Entry Point (**OEP**)).

Dynamic Anti-Debugging -- Exception

■ **Structured exception handling (SEH)** is a Microsoft extension to C to handle certain exceptional code situations, such as hardware faults, gracefully.

Microsoft-specific:

Grammar

`try-except-statement :`

`__try compound-statement __except (expression) compound-statement`

`try-finally-statement :`

`__try compound-statement __finally compound-statement`

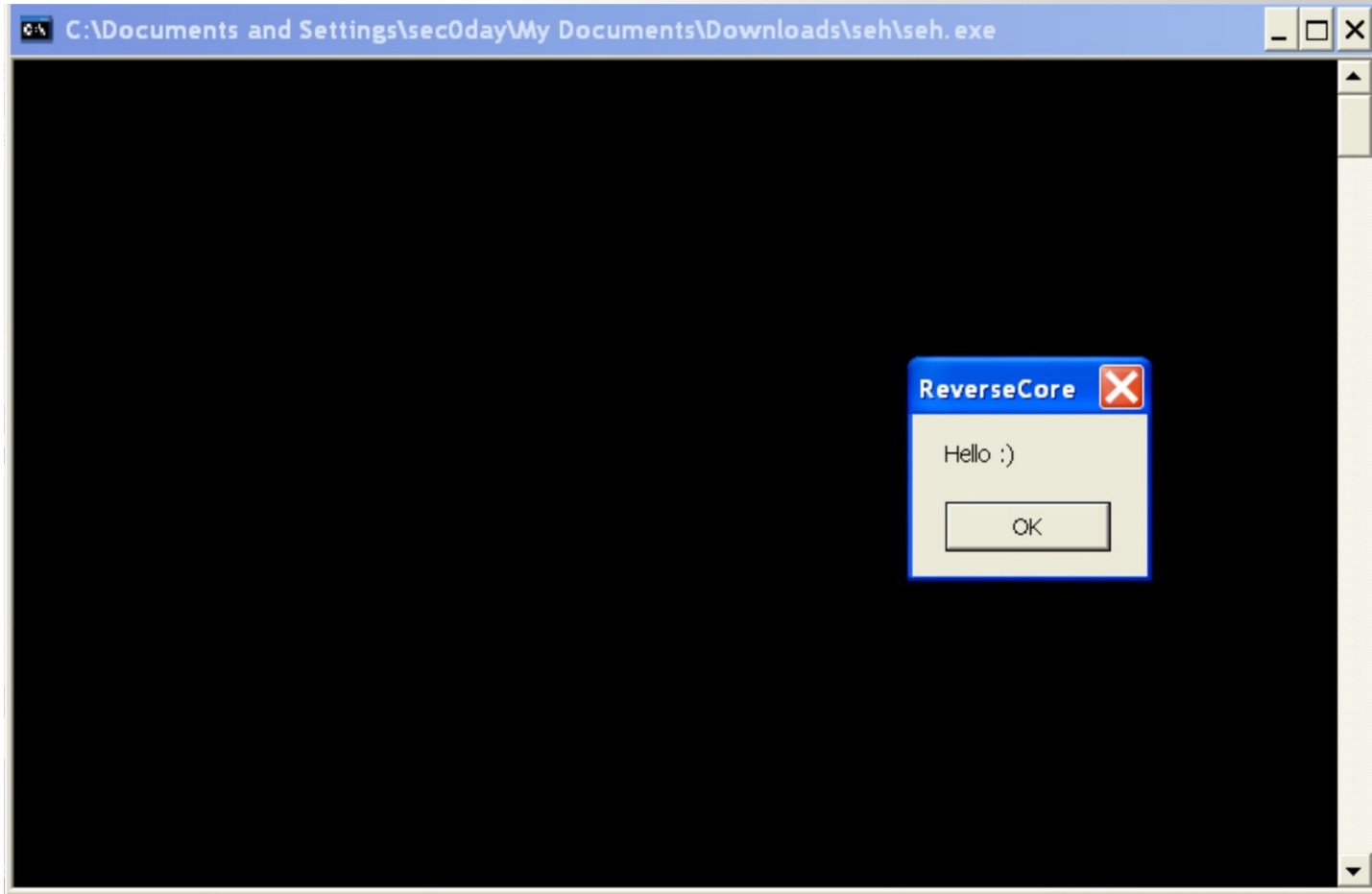
```
void fault_nocatch_fin(void) {
    __try
    {
        __try
        {
            sehR = *sehD;
        }
        __finally
        {
            TEST_STEP(17)
        }
    }
    __except (EvalFilter_dll(EXCEPTION_CONTINUE_SEARCH))
    {
        TEST_STEP(41)
    }
}
```

Although Windows and Microsoft C++ support SEH, we recommend that you use ISO-standard C++ exception handling. It makes your code more portable and flexible. -- MSDN

Typical Exceptions in Windows System

```
#define EXCEPTION_ACCESS_VIOLATION      0xC0000005u
#define EXCEPTION_DATATYPE_MISALIGNMENT 0x80000002u
#define EXCEPTION_BREAKPOINT            0x80000003u
#define EXCEPTION_SINGLE_STEP           0x80000004u
#define EXCEPTION_ARRAY_BOUNDS_EXCEEDED 0xC000008Cu
#define EXCEPTION_FLT_DENORMAL_OPERAND  0xC000008Du
#define EXCEPTION_FLT_DIVIDE_BY_ZERO     0xC000008Eu
#define EXCEPTION_FLT_INEXACT_RESULT     0xC000008Fu
#define EXCEPTION_FLT_INVALID_OPERATION  0xC0000090u
#define EXCEPTION_FLT_OVERFLOW           0xC0000091u
#define EXCEPTION_FLT_STACK_CHECK        0xC0000092u
#define EXCEPTION_FLT_UNDERFLOW          0xC0000093u
#define EXCEPTION_INT_DIVIDE_BY_ZERO     0xC0000094u
#define EXCEPTION_INT_OVERFLOW           0xC0000095u
#define EXCEPTION_PRIV_INSTRUCTION       0xC0000096u
#define EXCEPTION_IN_PAGE_ERROR          0xC0000006u
#define EXCEPTION_ILLEGAL_INSTRUCTION    0xC000001Du
#define EXCEPTION_NONCONTINUABLE_EXCEPTION 0xC0000025u
#define EXCEPTION_STACK_OVERFLOW         0xC00000FDu
#define EXCEPTION_INVALID_DISPOSITION    0xC0000026u
#define EXCEPTION_GUARD_PAGE             0x80000001u
#define EXCEPTION_INVALID_HANDLE         0xC0000008u
```

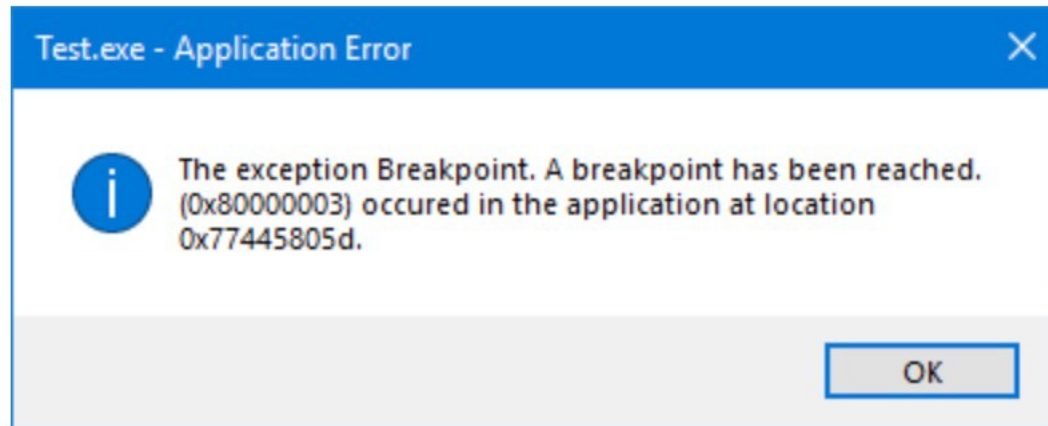
SEH Example – SEH.exe



EXCEPTION_BREAKPOINT

```
#define EXCEPTION_BREAKPOINT
```

```
0x80000003u
```



Program will automatically call the registered SEH. If the program is running under the Debug mode, it will stop the program and give the control back to the debugger.

SEH Example – DynAD_SEH.exe

OllyDbg - DynAD_SEH.exe - [CPU - main thread, module DynAD_SE]

File View Debug Plugins Options Window Help

LEMTW H C / K B R ... S

00401000 \$ 55 PUSH EBP
 00401001 . 8BEC MOV EBP,ESP
 00401003 . 53 PUSH EBX
 00401004 . 68 A0994000 PUSH DynAD_SE.004099A0
 00401009 . E8 69000000 CALL DynAD_SE.00401077
 0040100E . 83C4 04 ADD ESP,4
 00401011 . 68 2C104000 PUSH DynAD_SE.0040102C
 00401016 . 64:FF35 00000000 PUSH DWORD PTR FS:[0]
 0040101D . 64:8925 00000000 MOV DWORD PTR FS:[0],ESP
 00401024 . CC INT3
 00401025 . B8 FFFFFFFF MOV EAX,-1
 0040102A . FFE0 JMP EAX
 0040102C \$ 36:8B4424 0C MOV EAX,DWORD PTR SS:[ESP+C]
 00401031 . BB 40104000 MOV EBX,DynAD_SE.00401040
 00401036 . 3E:8998 B8000000 MOV DWORD PTR DS:[EAX+B8],EBX
 0040103D . 33C0 XOR EAX,EAX
 0040103F . C3 RETN
 00401040 . 64:8F05 00000000 POP DWORD PTR FS:[0]
 00401047 . 83C4 04 ADD ESP,4
 0040104A . 68 B4994000 PUSH DynAD_SE.004099B4
 0040104F . E8 23000000 CALL DynAD_SE.00401077
 00401057 . 8B4424 0C MOV EAX,DWORD PTR SS:[ESP+C]
 0040105D . 3E:8998 B8000000 MOV DWORD PTR DS:[EAX+B8],EBX
 00401064 . 33C0 XOR EAX,EAX
 00401066 . C3 RETN

ASCII "SEH : Br
 SE handler inst
 Structured exce
 ASCII " => No

Registers (MMX)

00000000
 0012FFB0
 7C90E514 ntdll.KiFastSystemCallRet
 7FFD7000
 0012FFC4
 0012FFF0
 FFFFFFFF
 7C910228 ntdll.7C910228
 004012BE DynAD_SE.<ModuleEntryPoint>
 ES 0023 32bit 0(FFFFFFFF)
 CS 001B 32bit 0(FFFFFFFF)
 SS 0023 32bit 0(FFFFFFFF)
 DS 0023 32bit 0(FFFFFFFF)
 FS 003B 32bit 7FFDF000(FFF)
 GS 0000 NULL
 LastErr ERROR_SUCCESS (00000000)
 00000246 (NO,NB,E,BE,NS,PE,GE,LE)
 0105 0104 0073 0064
 006F 005C 0030 0031
 0069 002E 0067 0062
 0000 0000 0000 0000
 0000 0000 0000 0000
 0012FFC4 7C81776F RETURN to kernel32.7C81776F
 0012FFC8 7C910228 ntdll.7C910228
 0012FFCC FFFFFFFF
 0012FFD0 7FFD7000
 0012FFD4 8054B6ED
 0012FFD8 0012FFC8
 0012FFDC 897A4520
 0012FFE0 FFFFFFFF End of SEH chain
 0012FFE4 7C839A90 SE handler
 0012FFEB 7C817778 kernel32.7C817778

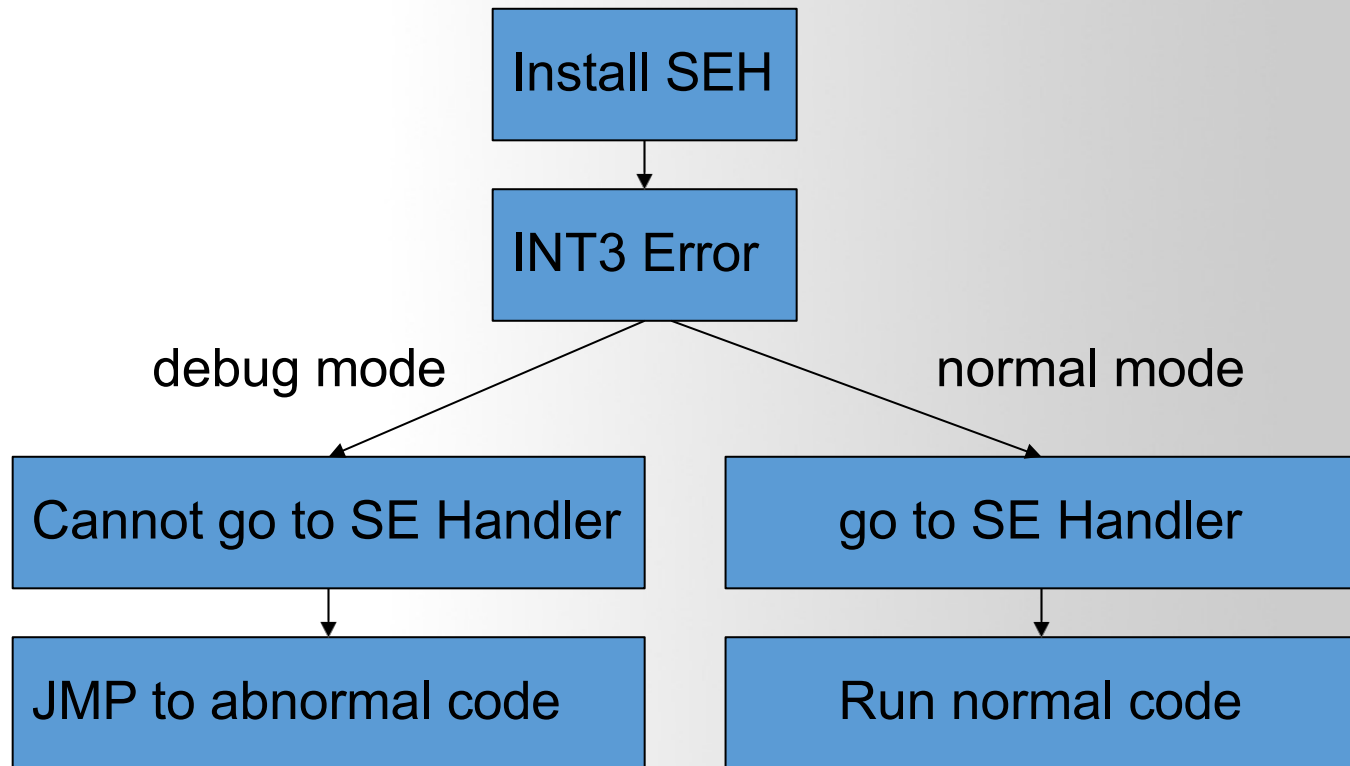
Local call from 00401060

| Address | Hex dump | ASCII |
|----------|-------------------------|-----------|
| 0040B000 | 01 00 00 00 4E E6 40 BB | 0...Np01 |
| 0040B008 | B1 19 BF 44 00 00 00 00 | 1D.... |
| 0040B010 | 80 CC 40 00 00 00 00 00 | CFe.... |
| 0040B018 | 80 CC 40 00 01 01 00 00 | CFe.00.. |
| 0040B020 | 00 00 00 00 00 00 00 00 | |
| 0040B028 | 00 10 00 00 00 00 00 00 | |
| 0040B030 | 00 00 00 00 00 00 00 00 | |
| 0040B038 | 00 00 00 00 02 00 00 00 |0... |
| 0040B040 | 01 00 00 00 00 00 00 00 | 0..... |

Analysing DynAD_SE: 174 heuristical procedures, 119 calls to known, 93 calls to guessed functions

Paused

SEH Example – DynAD_SEH.exe



SEH Example – DynAD_SEH.exe

Install SEH

| | | | |
|----------|--------------------|--------------------------|-------------------------|
| 00401011 | . 68 2C104000 | PUSH DynAD_SE.0040102C | SE handler installation |
| 00401016 | . 64:FF35 00000000 | PUSH DWORD PTR FS:[0] | |
| 0040101D | . 64:8925 00000000 | MOV DWORD PTR FS:[0],ESP | |

| | | |
|----------|------|------|
| 00401024 | . CC | INT3 |
|----------|------|------|

INT3 Error

debug mode

normal mode

Cannot go to SE Handler

go to SE Handler

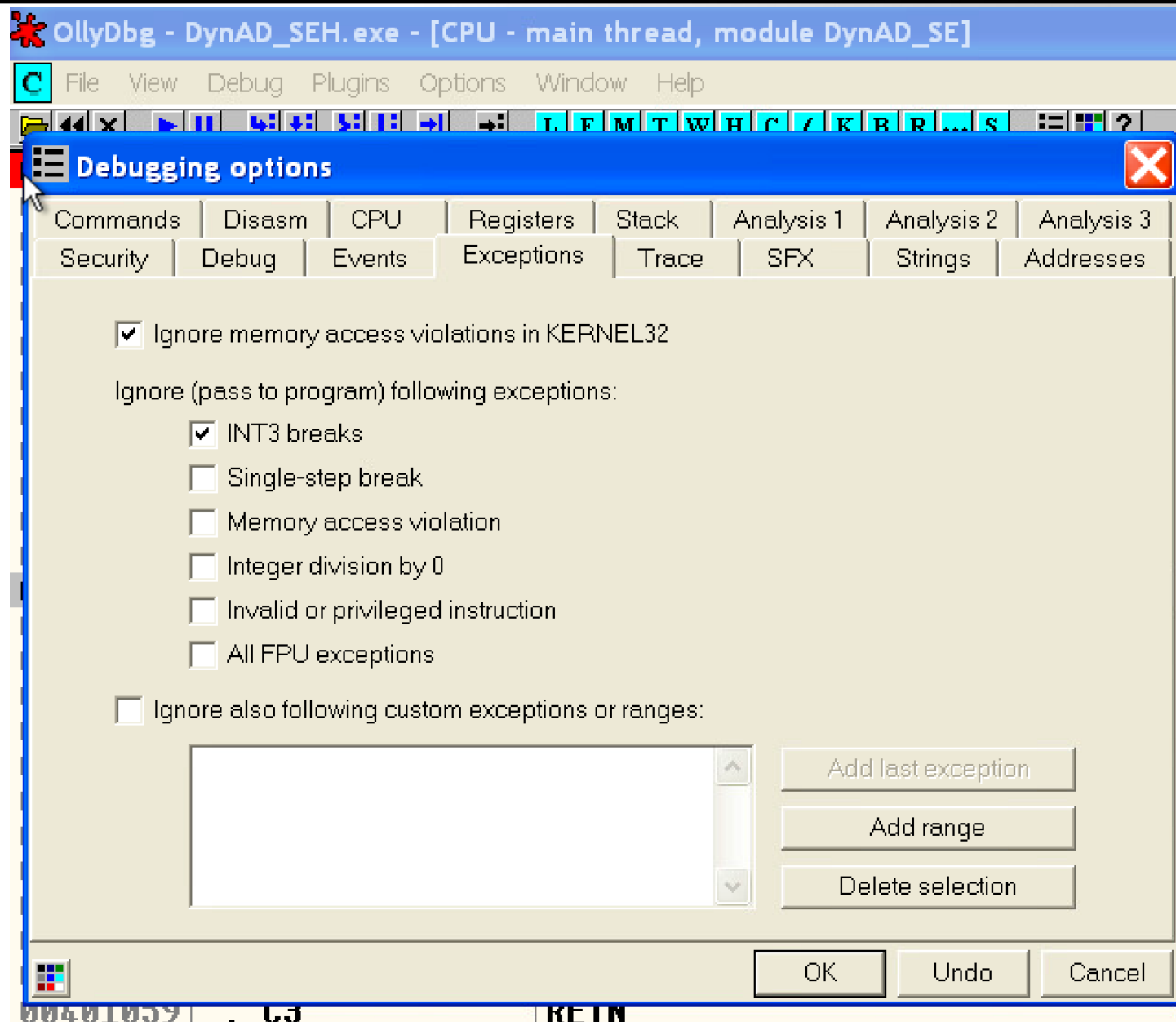
JMP to abnormal code

Run normal code

| | | |
|----------|---------------|------------|
| 00401025 | . B8 FFFFFFFF | MOV EAX,-1 |
| 0040102A | . FFE0 | JMP EAX |

| | | | |
|----------|------------------|-------------------------------|------------------------------|
| 0040102C | * 36:8B4424 0C | MOV EAX,DWORD PTR SS:[ESP+C] | Structured exception handler |
| 00401031 | . BB 40104000 | MOV EBX,DynAD_SE.00401040 | |
| 00401036 | . 3E:8998 B80000 | MOV DWORD PTR DS:[EAX+B8],EBX | |
| 0040103D | . 33C0 | XOR EAX,EAX | |
| 0040103F | . C3 | RETN | |

How to bypass INT3 breaks



***Get 1st Time (T1)**

A bunch of code
-loop
-garbage code
-encryption/decryption

***Get 2nd Time (T2)**

**If $T2 - T1 > 1$ (sec)
Call `ExitProcess()`**

Aka **Anti-Emulating**

How to calculate time intervals

■ Counter based method

- RDTSC (Read Time Stamp Counter)
- kernel32!QueryPerformanceCounter()/ntdll!NtQueryPerformanceCounter()
- kernel32!GetTickCount()

■ Time based method

- timeGetTime()
- _ftime()

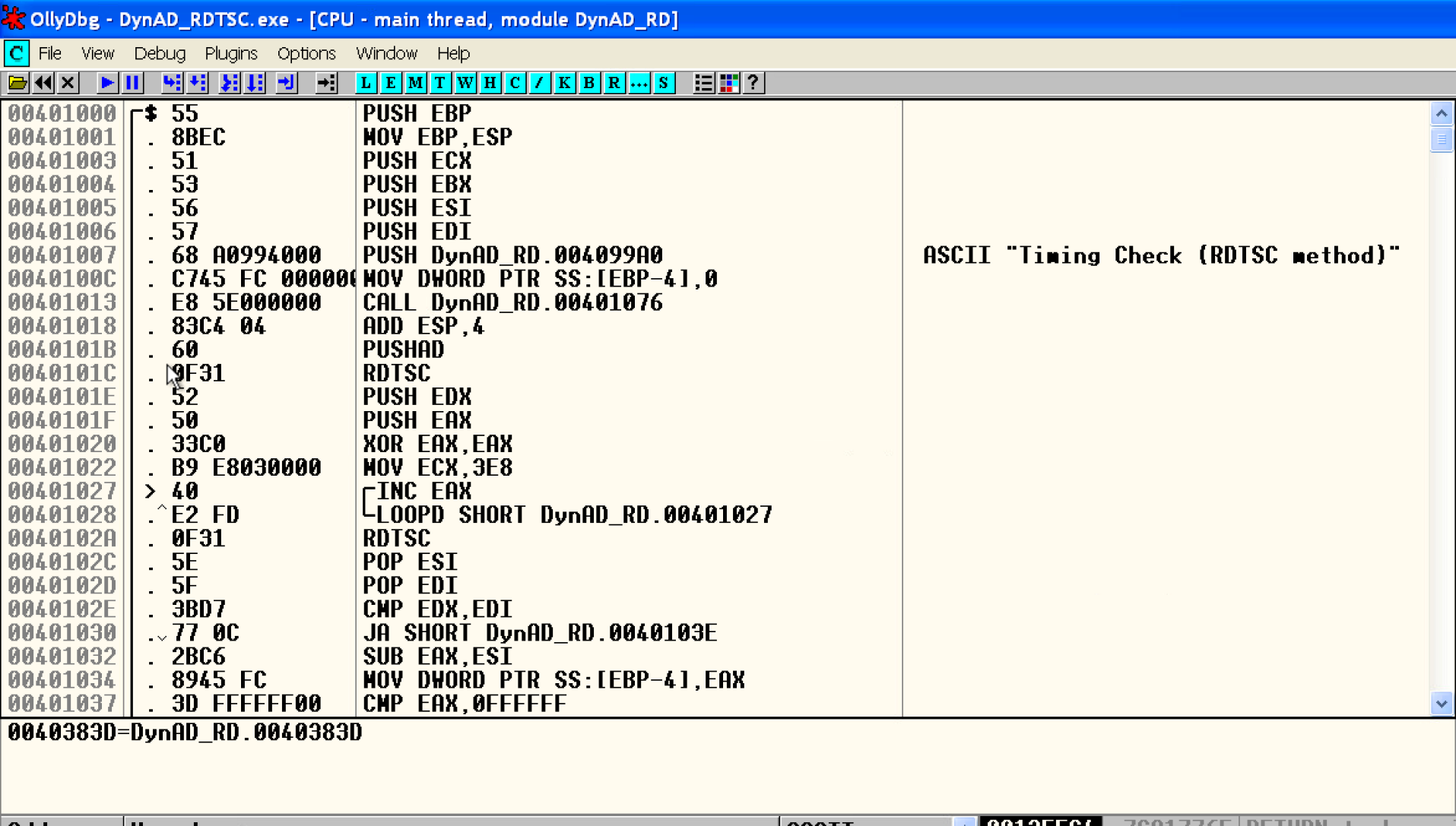
Use CPU counter
Or system time

Timing Check Example – DynAD_RDTSC.exe

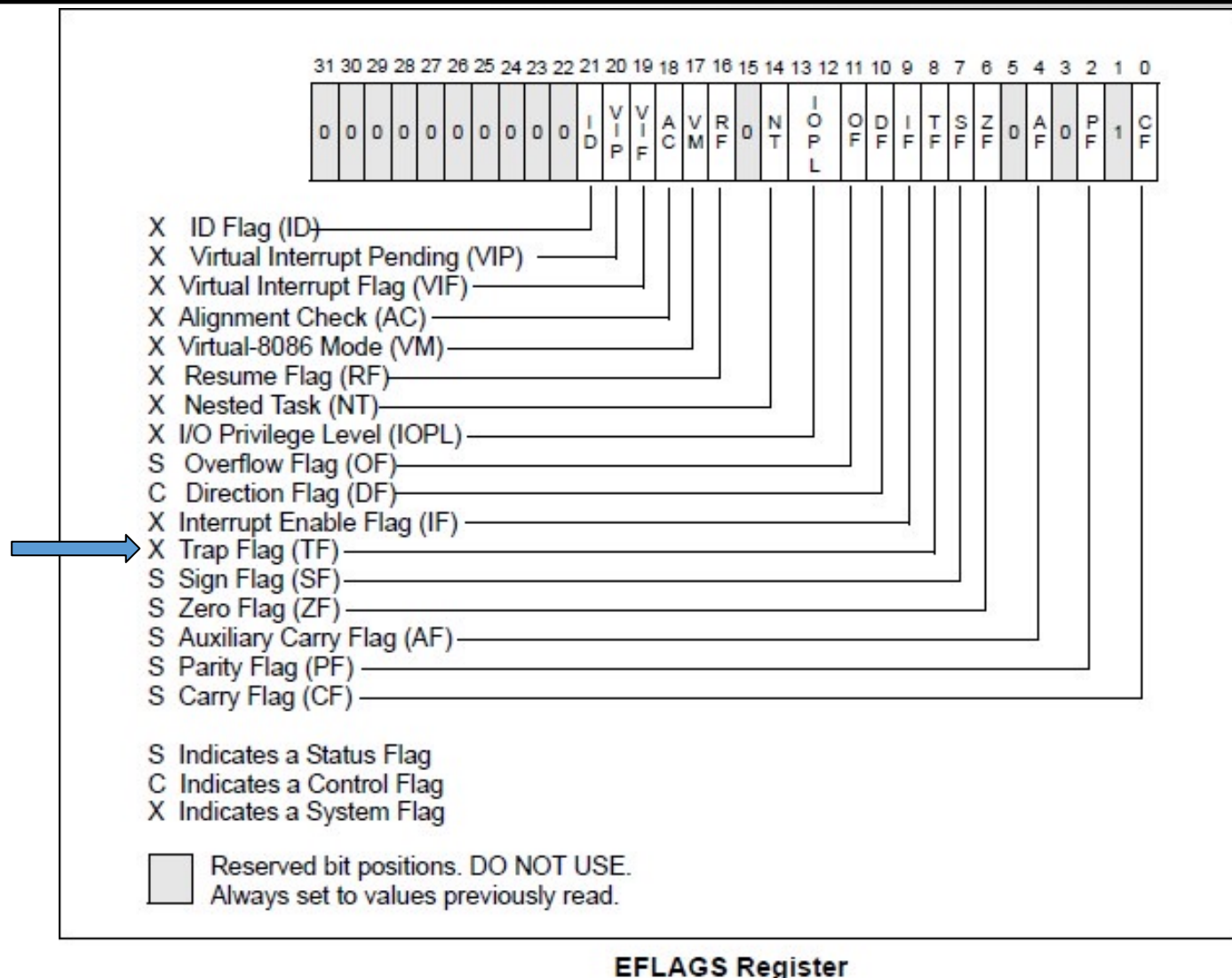
The **Time Stamp Counter (TSC)** is a 64-bit [register](#) present on all [x86](#) processors since the [Pentium](#). It counts the number of CPU [cycles](#) since its reset.

The instruction **RDTSC** returns the TSC in **EDX:EAX**. In [x86-64](#) mode, RDTSC also clears the upper 32 bits of [RAX](#) and [RDX](#). Its [opcode](#) is 0F 31

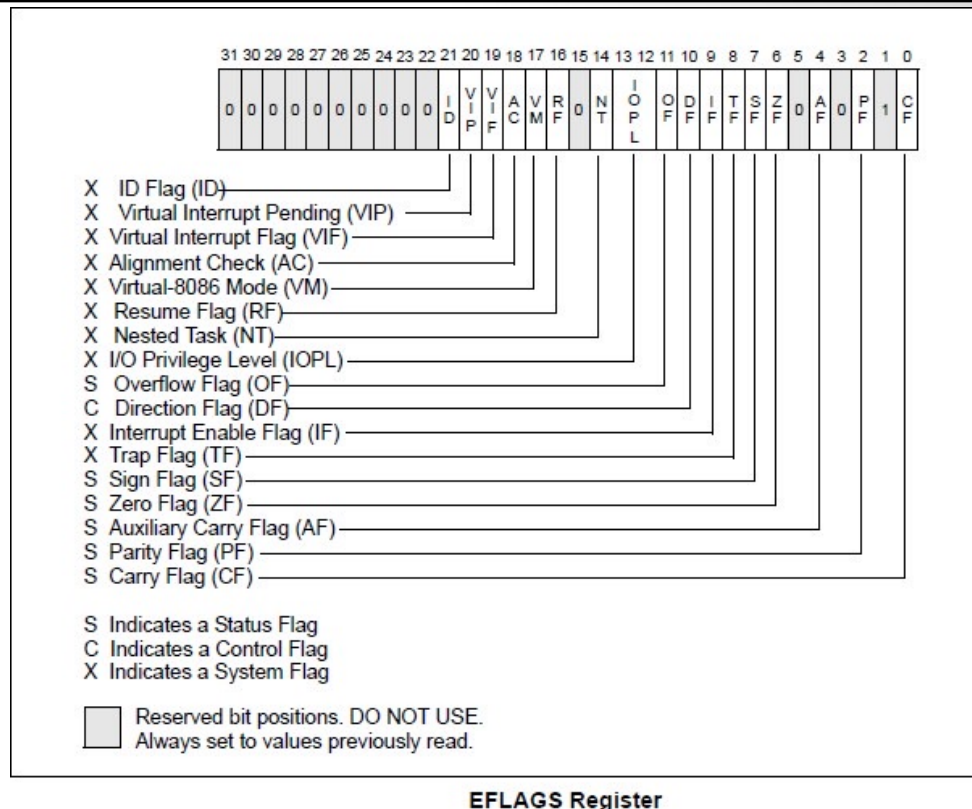
Timing Check Example – DynAD_RDTSC.exe



Trap Flag



Compare Checksum – DynAD_SingleStep.exe



■ When TF is 1, CPU is switching to Single Step mode, each time CPU execute a command will trigger one EXCEPTION_SINGLE_STEP exception. And TF will reset to 0 automatically.

Breakpoint Detection

■ When we debug the program, we usually set a breakpoint

- breakpoint → x86 command is 0xCC
- if malware detect 0xCC while running, then it will terminate itself

■ How to detect 0xCC?

```
CC 3D CC100001 MOV EDI,DWORD PTR DS:[10010CC]
```

Can we just scanning for string 0xCC?

Breakpoint Detection – API Breakpoint Detection

■ Method 1: Detect API Breakpoint

- Most (experienced) code reverse engineer set a breakpoint for the following API:
 - **[Process]:** CreateProcess, CreateThread, EnumProcessModules, OpenProcess, TerminateProcess, ShellExecuteA, CreateRemoteThread, CreateProcessAsUser, EnumProcess...
 - **[Memory]:** ReadProcessMemory, WriteProcessMemory, VirtualAlloc, VirtualProtect, VirtualQuery...
 - **[File]:** CreateFile, ReadFile, WriteFile, CopyFile, CreateDirectory, DeleteFile, MoveFile, GetFileSize...
 - **[Register]:** RegCreateKeyEx, RegDeleteKey, RegSetValue
 - **[Network]:** WSASStartup, socket, inet_addr, recv, send, HttpOpenRequest

Malware just need to check if the first byte of these functions is changed to 0XCC

Breakpoint Detection

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- Most (experienced) code reverse engineer set a breakpoint for the following API:
 - **[Process]:** CreateProcess, CreateThread, EnumProcessModules, OpenProcess, TerminateProcess, ShellExecuteA, CreateRemoteThread, CreateProcessAsUser, EnumProcess...
 - **[Memory]:** ReadProcessMemory, WriteProcessMemory, VirtualAlloc, VirtualProtect, VirtualQuery...
 - **[File]:** CreateFile, ReadFile, WriteFile, CopyFile, CreateDirectory, DeleteFile, MoveFile, GetFileSize...
 - **[Register]:** RegCreateKeyEx, RegDeleteKey, RegSetValue
 - **[Network]:** WSASStartup, socket, inet_addr, recv, send, HttpOpenRequest

Malware just need to check if the first byte of these functions is changed to 0XCC

Breakpoint Detection – Code Checksum Comparison

```

00401181 . 75 0B      JNZ SHORT DynAD_Si.0040118E
00401183 . 56        PUSH ESI
00401184 . 56        PUSH ESI
00401185 . 6A 01     PUSH 1
00401187 . 56        PUSH ESI
00401188 . FF15 04804000 CALL DWORD PTR DS:[<&KERNEL32.HeapSetInf
0040118E > B8 4D5A0000 MOV EAX,5A4D
00401193 . 66:3905 00004000 CMP WORD PTR DS:[400000],AX
0040119A . 74 05     JE SHORT DynAD_Si.004011A1
0040119C > 8975 E4   MOV DWORD PTR SS:[EBP-1C],ESI
0040119F . EB 36     JMP SHORT DynAD_Si.004011D7
004011A1 > A1 3C004000 MOV EAX,DWORD PTR DS:[40003C]
004011A6 . 81B8 00004000 CMP DWORD PTR DS:[EAX+400000],4550
004011B0 . 75 EA     JNZ SHORT DynAD_Si.0040119C
004011B2 . 80 00010000 MOV ECX,100

```

➡ 0x12345678

Checksum

```

00401181 CC 0B      JNZ SHORT DynAD_Si.0040118E
00401183 . 56        PUSH ESI
00401184 . 56        PUSH ESI
00401185 . 6A 01     PUSH 1
00401187 . 56        PUSH ESI
00401188 . FF15 04804000 CALL DWORD PTR DS:[<&KERNEL32.HeapSetInf
0040118E > B8 4D5A0000 MOV EAX,5A4D
00401193 . 66:3905 00004000 CMP WORD PTR DS:[400000],AX
0040119A . 74 05     JE SHORT DynAD_Si.004011A1
0040119C > 8975 E4   MOV DWORD PTR SS:[EBP-1C],ESI
0040119F . EB 36     JMP SHORT DynAD_Si.004011D7
004011A1 > A1 3C004000 MOV EAX,DWORD PTR DS:[40003C]
004011A6 . 81B8 00004000 CMP DWORD PTR DS:[EAX+400000],4550
004011B0 . 75 EA     JNZ SHORT DynAD_Si.0040119C
004011B2 . 80 00010000 MOV ECX,100

```

➡ 0xD71A5CA2

Compare Checksum – DynAD_Checksum.exe

Q & A

