Hands-on Learning Exercise 2 to Accompany Chapter 4:

Assembling With Cygwin/NASM and Shellcode

Here is a basic helloworld.asm program in x86 assembly.

```
;msgbox.asm
[SECTION .text]

global _start


_start:
      ;eax holds return value
      ;ebx will hold function addresses
      ;ecx will hold string pointers
      ;edx will hold NULL


      xor eax,eax
      xor ebx,ebx             ;zero out the registers
      xor ecx,ecx
      xor edx,edx

      jmp short GetLibrary
LibraryReturn:
      pop ecx                       ;get the library string
      mov [ecx + 10], dl            ;insert NULL
      mov ebx, 0x7c801d7b           ;LoadLibraryA(libraryname);
      push ecx                ;beginning of user32.dll
      call ebx                ;eax will hold the module handle

      jmp short FunctionName
FunctionReturn:

      pop ecx                       ;get the address of the Function string
      xor edx,edx
      mov [ecx + 11],dl       ;insert NULL
      push ecx
      push eax
      mov ebx, 0x7c80ae30           ;GetProcAddress(hmodule,functionname);
      call ebx                ;eax now holds the address of MessageBoxA

      jmp short Message
MessageReturn:
```

```
      pop ecx                       ;get the message string
      xor edx,edx
      mov [ecx+3],dl                ;insert the NULL

      xor edx,edx

      push edx                ;MB_OK
      push ecx                ;title
      push ecx                ;message
      push edx                ;NULL window handle

      call eax                ;MessageBoxA(windowhandle,msg,title,type); Address

ender:
      xor edx,edx
      push eax
      mov eax, 0x7c81cafa           ;exitprocess(exitcode);
      call eax                ;exit cleanly so we don't crash the parent program


      ;the N at the end of each string signifies the location of the NULL
      ;character that needs to be inserted

GetLibrary:
      call LibraryReturn
      db 'user32.dllN'
FunctionName
      call FunctionReturn
      db 'MessageBoxAN'
Message
      call MessageReturn
      db 'HeyN'
```

Copy and paste this a text editor and name the file hello.asm

This is the same basic program as the first tutorial but is formatted using NASM directives. NASM is another assembler.

Open Cygwin and type the following commands.

```
User@malware ~/asm
$ nasm -f elf hello.asm; ld -o hello hello.o; objdump -d hello
```

This is actually 3 commands together, each separated by a semicolon.

```
nasm –f elf hello.asm         ;     This assembles hello.asm as an elf binary

ld –o hello hello.o           ;     This links hello.o and creates the .
                          executable hello
objdump –d hello              ;     This disassembles the binary hello
```

If all goes correctly, you should get the following output:

```
Disassembly of section .text:

00401000 <_start>:
  401000:       31 c0                   xor    %eax,%eax
  401002:       31 db                   xor    %ebx,%ebx
  401004:       31 c9                   xor    %ecx,%ecx
  401006:       31 d2                   xor    %edx,%edx
  401008:       eb 37                   jmp    401041 <GetLibrary>

0040100a <LibraryReturn>:
  40100a:       59                      pop    %ecx
  40100b:       88 51 0a                mov    %dl,0xa(%ecx)
  40100e:       bb 7b 1d 80 7c          mov    $0x7c801d7b,%ebx
  401013:       51                      push   %ecx
  401014:       ff d3                   call   *%ebx
  401016:       eb 39                   jmp    401051 <FunctionName>

00401018 <FunctionReturn>:
  401018:       59                      pop    %ecx
  401019:       31 d2                   xor    %edx,%edx
  40101b:       88 51 0b                mov    %dl,0xb(%ecx)
  40101e:       51                      push   %ecx
  40101f:       50                      push   %eax
  401020:       bb 30 ae 80 7c          mov    $0x7c80ae30,%ebx
  401025:       ff d3                   call   *%ebx
  401027:       eb 39                   jmp    401062 <Message>

00401029 <MessageReturn>:
  401029:       59                      pop    %ecx
  40102a:       31 d2                   xor    %edx,%edx
  40102c:       88 51 03                mov    %dl,0x3(%ecx)
  40102f:       31 d2                   xor    %edx,%edx
  401031:       52                      push   %edx
  401032:       51                      push   %ecx
  401033:       51                      push   %ecx
  401034:       52                      push   %edx
  401035:       ff d0                   call   *%eax

00401037 <ender>:
  401037:       31 d2                   xor    %edx,%edx
  401039:       50                      push   %eax
  40103a:       b8 fa ca 81 7c          mov    $0x7c81cafa,%eax
  40103f:       ff d0                   call   *%eax

00401041 <GetLibrary>:
  401041:       e8 c4 ff ff ff          call   40100a <LibraryReturn>
  401046:       75 73                   jne    4010bb <__DTOR_LIST__+0x48>
  401048:       65                      gs
  401049:       72 33                   jb     40107e <__DTOR_LIST__+0xb>
  40104b:       32 2e                   xor    (%esi),%ch
  40104d:       64                      fs
  40104e:       6c                      insb   (%dx),%es:(%edi)
  40104f:       6c                      insb   (%dx),%es:(%edi)
  401050:       4e                      dec    %esi

00401051 <FunctionName>:
  401051:       e8 c2 ff ff ff          call   401018 <FunctionReturn>
  401056:       4d                      dec    %ebp
  401057:       65                      gs
  401058:       73 73                   jae    4010cd <__DTOR_LIST__+0x5a>
  40105a:       61                      popa
  40105b:       67                      addr16
  40105c:       65                      gs
  40105d:       42                      inc    %edx
  40105e:       6f                      outsl  %ds:(%esi),(%dx)
  40105f:       78 41                   js     4010a2 <__DTOR_LIST__+0x2f>
  401061:       4e                      dec    %esi

00401062 <Message>:
  401062:       e8 c2 ff ff ff          call   401029 <MessageReturn>
  401067:       48                      dec    %eax
  401068:       65                      gs
  401069:       79 4e                   jns    4010b9 <__DTOR_LIST__+0x46>

0040106b <__CTOR_LIST__>:
  40106b:       ff                      (bad)
  40106c:       ff                      (bad)
  40106d:       ff                      (bad)
  40106e:       ff 00                   incl   (%eax)
  401070:       00 00                   add    %al,(%eax)
        ...

00401073 <__DTOR_LIST__>:
  401073:       ff                      (bad)
  401074:       ff                      (bad)
  401075:       ff                      (bad)
  401076:       ff 00                   incl   (%eax)
  401078:       00 00                   add    %al,(%eax)
        ...
```

We are just interested in these sections:

```
Disassembly of section .text:

00401000 <_start>:
  401000:       31 c0                   xor    %eax,%eax
  401002:       31 db                   xor    %ebx,%ebx
  401004:       31 c9                   xor    %ecx,%ecx
  401006:       31 d2                   xor    %edx,%edx
  401008:       eb 37                   jmp    401041 <GetLibrary>

0040100a <LibraryReturn>:
  40100a:       59                      pop    %ecx
  40100b:       88 51 0a                mov    %dl,0xa(%ecx)
  40100e:       bb 7b 1d 80 7c          mov    $0x7c801d7b,%ebx
  401013:       51                      push   %ecx
  401014:       ff d3                   call   *%ebx
  401016:       eb 39                   jmp    401051 <FunctionName>

00401018 <FunctionReturn>:
  401018:       59                      pop    %ecx
  401019:       31 d2                   xor    %edx,%edx
  40101b:       88 51 0b                mov    %dl,0xb(%ecx)
  40101e:       51                      push   %ecx
  40101f:       50                      push   %eax
  401020:       bb 30 ae 80 7c          mov    $0x7c80ae30,%ebx
  401025:       ff d3                   call   *%ebx
  401027:       eb 39                   jmp    401062 <Message>

00401029 <MessageReturn>:
  401029:       59                      pop    %ecx
  40102a:       31 d2                   xor    %edx,%edx
  40102c:       88 51 03                mov    %dl,0x3(%ecx)
  40102f:       31 d2                   xor    %edx,%edx
  401031:       52                      push   %edx
  401032:       51                      push   %ecx
  401033:       51                      push   %ecx
  401034:       52                      push   %edx
  401035:       ff d0                   call   *%eax

00401037 <ender>:
  401037:       31 d2                   xor    %edx,%edx
  401039:       50                      push   %eax
  40103a:       b8 fa ca 81 7c          mov    $0x7c81cafa,%eax
  40103f:       ff d0                   call   *%eax

00401041 <GetLibrary>:
  401041:       e8 c4 ff ff ff          call   40100a <LibraryReturn>
  401046:       75 73                   jne    4010bb <__DTOR_LIST__+0x48>
  401048:       65                      gs
  401049:       72 33                   jb     40107e <__DTOR_LIST__+0xb>
  40104b:       32 2e                   xor    (%esi),%ch
  40104d:       64                      fs
  40104e:       6c                      insb   (%dx),%es:(%edi)
  40104f:       6c                      insb   (%dx),%es:(%edi)
  401050:       4e                      dec    %esi

00401051 <FunctionName>:
  401051:       e8 c2 ff ff ff          call   401018 <FunctionReturn>
  401056:       4d                      dec    %ebp
  401057:       65                      gs
  401058:       73 73                   jae    4010cd <__DTOR_LIST__+0x5a>
  40105a:       61                      popa
  40105b:       67                      addr16
  40105c:       65                      gs
  40105d:       42                      inc    %edx
  40105e:       6f                      outsl  %ds:(%esi),(%dx)
  40105f:       78 41                   js     4010a2 <__DTOR_LIST__+0x2f>
  401061:       4e                      dec    %esi

00401062 <Message>:
  401062:       e8 c2 ff ff ff          call   401029 <MessageReturn>
  401067:       48                      dec    %eax
  401068:       65                      gs
  401069:       79 4e                   jns    4010b9 <__DTOR_LIST__+0x46>
0040106b <__CTOR_LIST__>:
  40106b:       ff                      (bad)
  40106c:       ff                      (bad)
  40106d:       ff                      (bad)
  40106e:       ff 00                   incl   (%eax)
  401070:       00 00                   add    %al,(%eax)
        ...

00401073 <__DTOR_LIST__>:
  401073:       ff                      (bad)
  401074:       ff                      (bad)
  401075:       ff                      (bad)
  401076:       ff 00                   incl   (%eax)
  401078:       00 00                   add    %al,(%eax)
        ...
```

These contain the hexadecimal numbers for our assembly code.

We see it starts with the hex numbers 31 c0 31 db 31 c9 31 d2 eb 37

```
Disassembly of section .text:

00401000 <_start>:
  401000:       31 c0                   xor    %eax,%eax
  401002:       31 db                   xor    %ebx,%ebx
  401004:       31 c9                   xor    %ecx,%ecx
  401006:       31 d2                   xor    %edx,%edx
  401008:       eb 37                   jmp    401041 <GetLibrary>
```

…

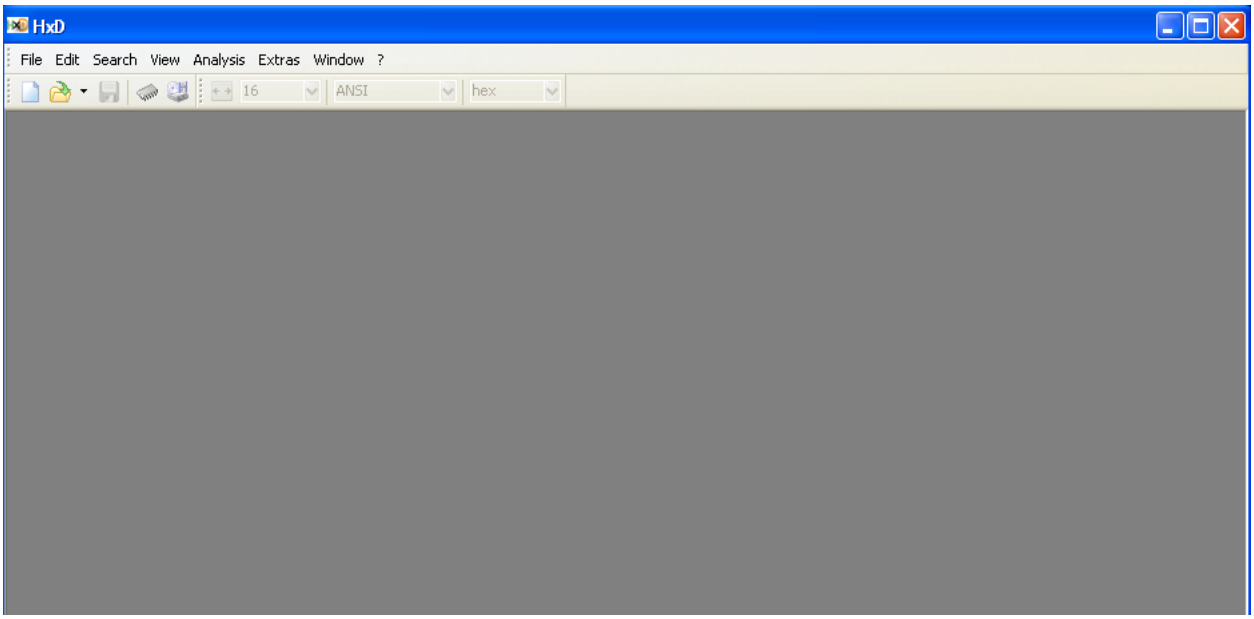
…

…

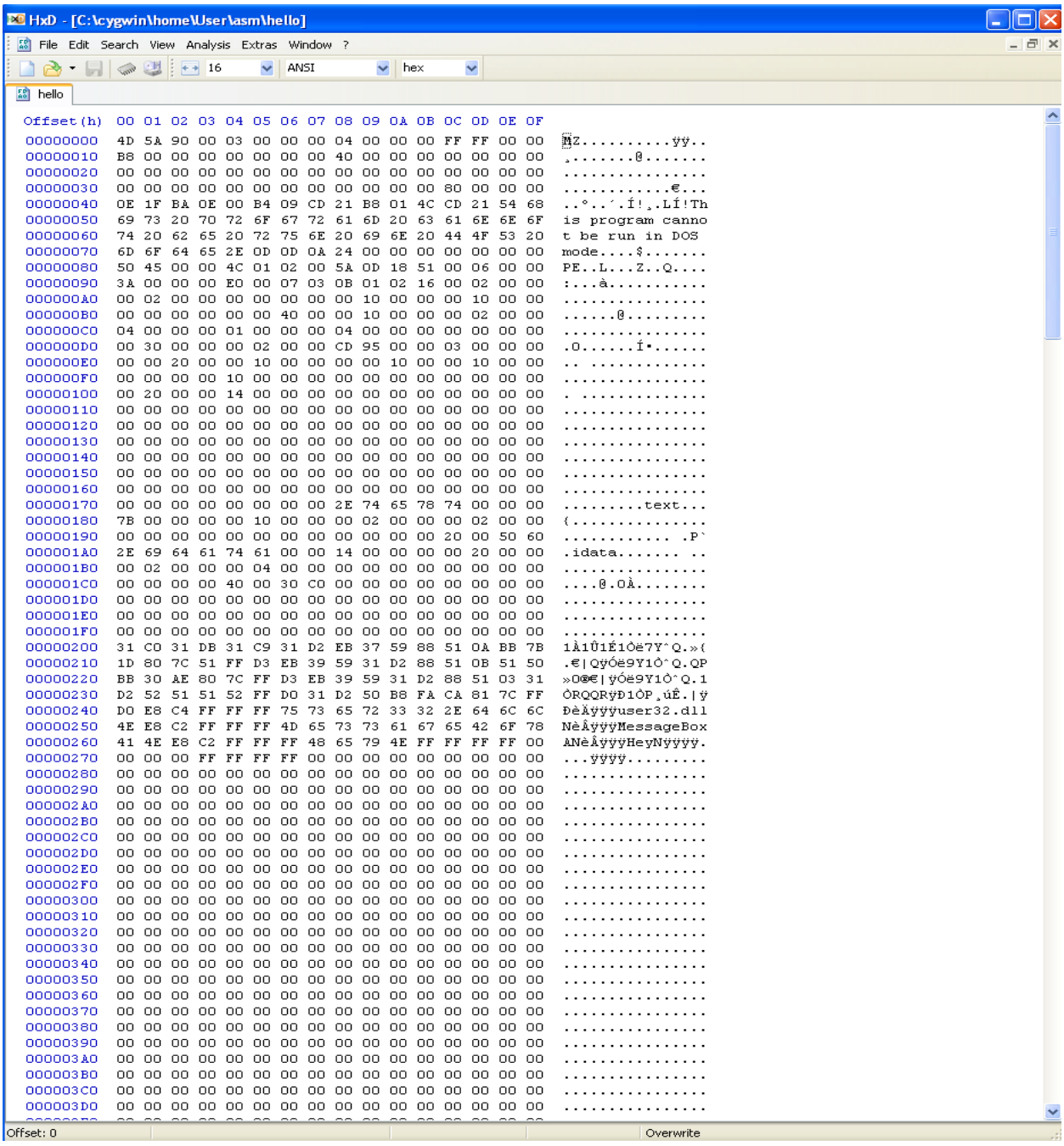
And the last section ends with e8 c2 ff ff ff 48 65 79 4e

```
0401062 <Message>:
 401062:       e8 c2 ff ff ff          call   401029 <MessageReturn>
 401067:       48                      dec    %eax
 401068:       65                      gs
 401069:       79 4e                   jns    4010b9 <__DTOR_LIST__+0x46>
```

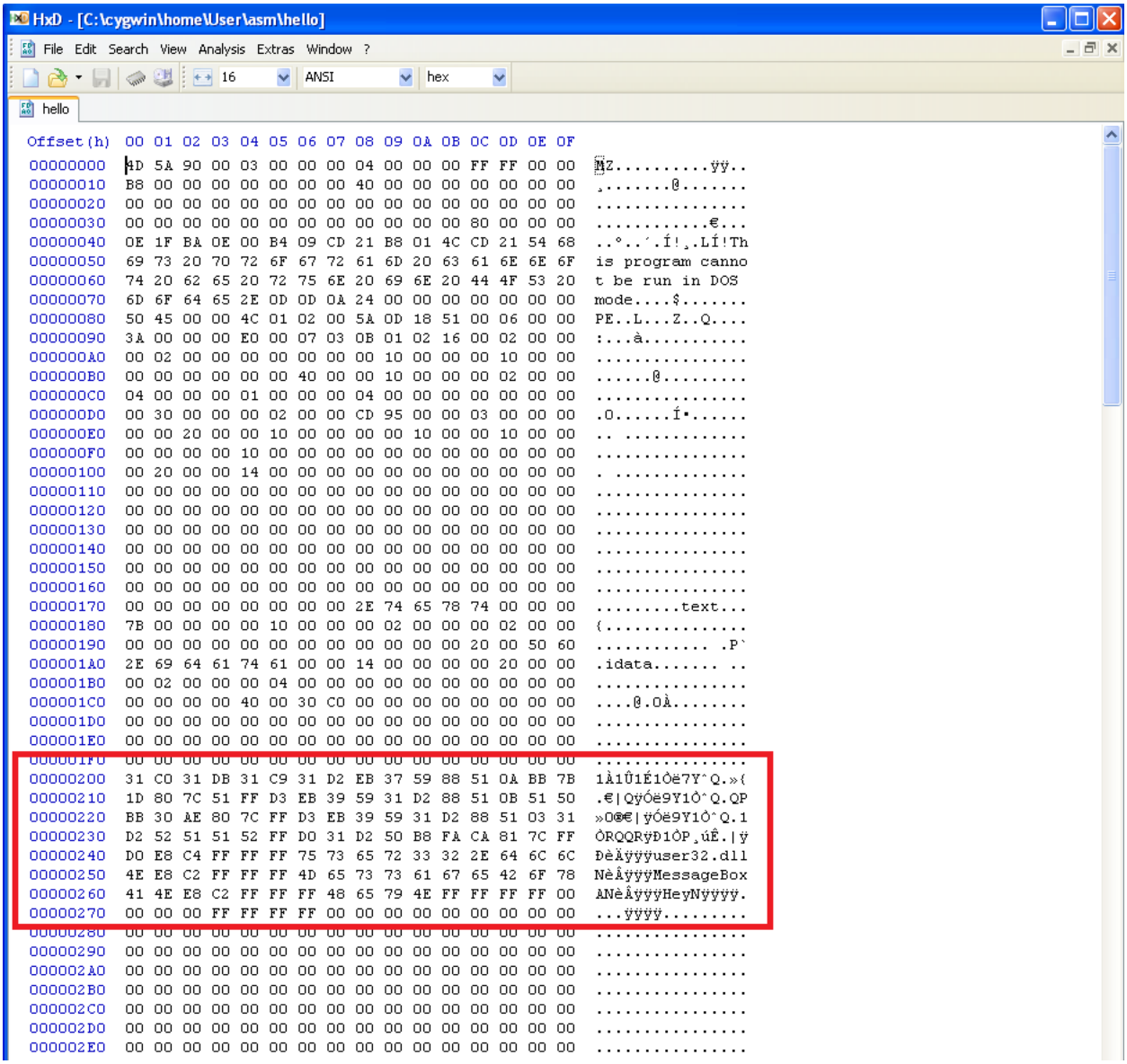
Let us now open the hello executable in the hex editor HxD. Start→Programs→HxD Hex Editor→HxD



Drag and drop the hello file into HxD. My file is located in C:\cygwin\home\User\hello because I just opened the Cygwin command prompt and did my work in the default directory. If you don't know where your file is, use windows search to find it.



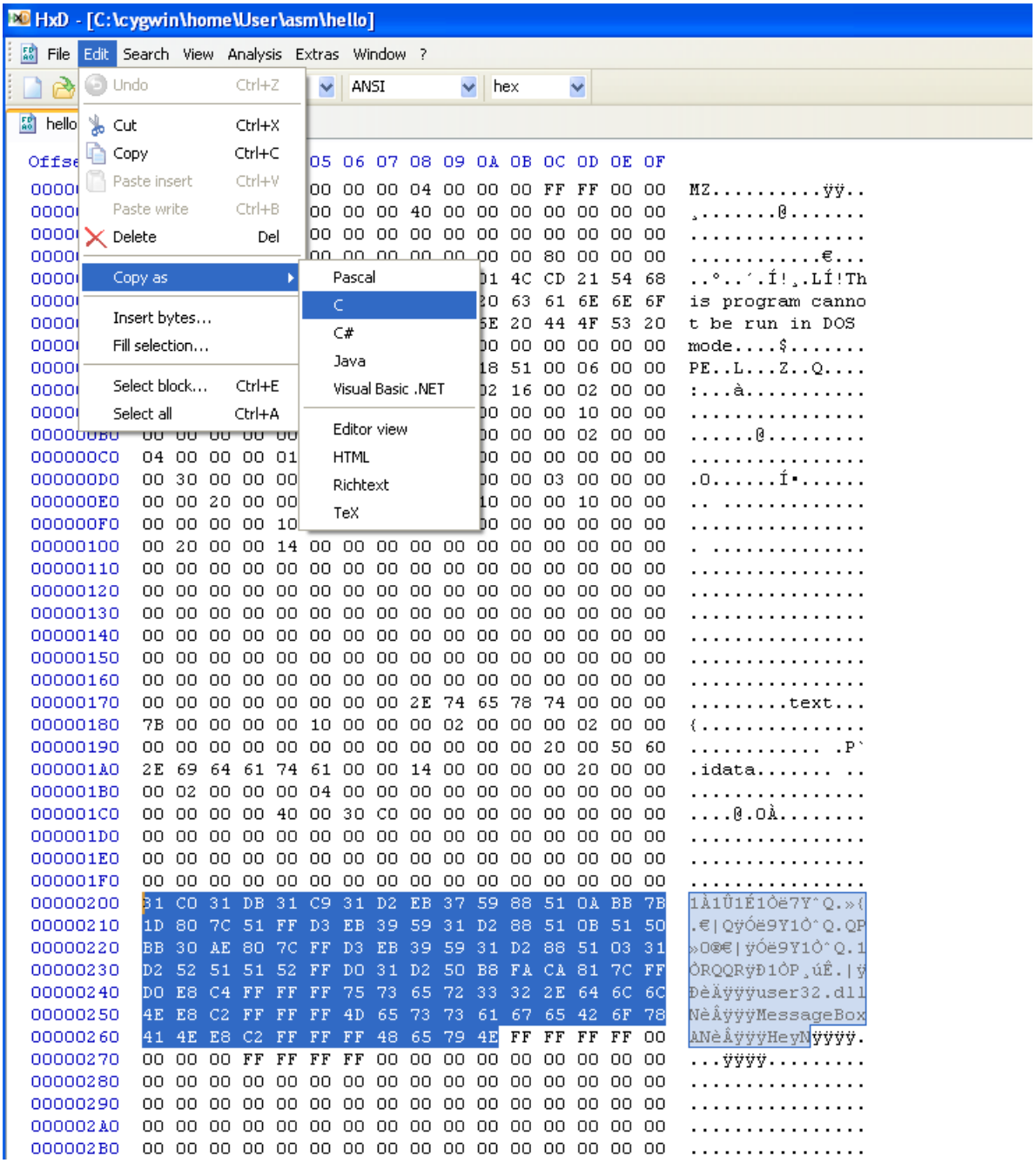
In the center you may notice the same hex numbers as we identified with objdump as being our assembly code.



Highlight from the 31 c0 to the 79 4e:

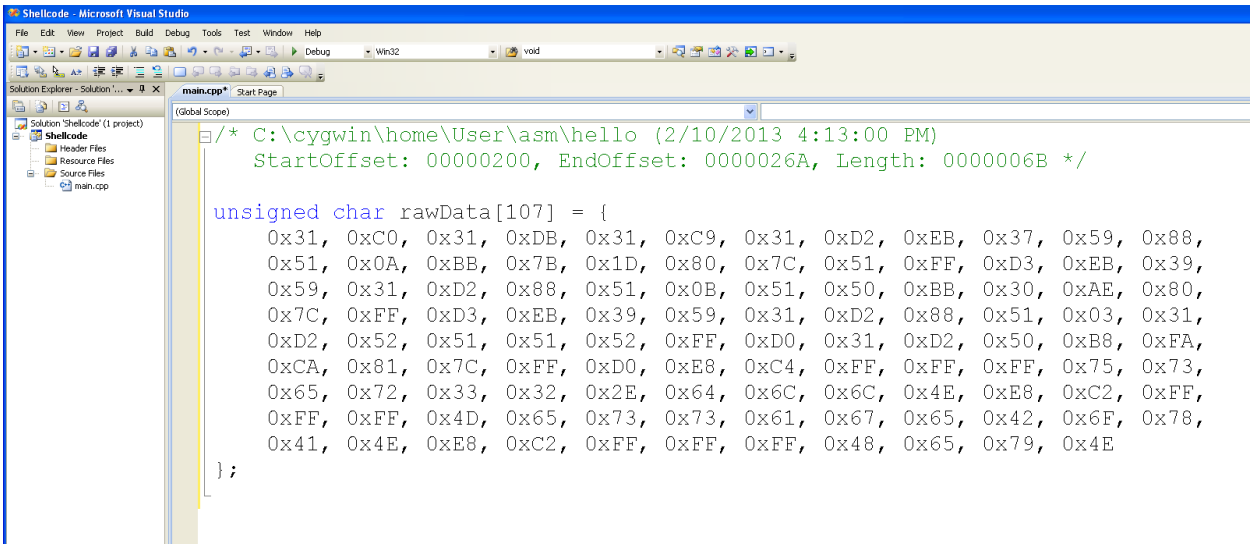
```
00000090  3A 00 00 00 E0 00 07 03 0B 01 02 16 00 02 00 00  :...à...........
000000A0  00 02 00 00 00 00 00 00 00 10 00 00 00 10 00 00  ................
000000B0  00 00 00 00 00 00 40 00 00 10 00 00 00 02 00 00  ......@.........
000000C0  04 00 00 00 01 00 00 00 04 00 00 00 00 00 00 00  ................
000000D0  00 30 00 00 00 02 00 00 CD 95 00 00 03 00 00 00  .0......Í•......
000000E0  00 00 20 00 00 10 00 00 00 00 10 00 00 10 00 00  .. .............
000000F0  00 00 00 00 10 00 00 00 00 00 00 00 00 00 00 00  ................
00000100  00 20 00 00 14 00 00 00 00 00 00 00 00 00 00 00  . ..............
00000110  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
00000120  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
00000130  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
00000140  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
00000150  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
00000160  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
00000170  00 00 00 00 00 00 00 00 2E 74 65 78 74 00 00 00  .........text...
00000180  7B 00 00 00 00 10 00 00 00 02 00 00 00 02 00 00  {...............
00000190  00 00 00 00 00 00 00 00 00 00 00 00 00 20 00 50  ............. .P
000001A0  2E 69 64 61 74 61 00 00 14 00 00 00 00 20 00 00  .idata....... ..
000001B0  00 02 00 00 00 04 00 00 00 00 00 00 00 00 00 00  ................
000001C0  00 00 00 00 40 00 30 C0 00 00 00 00 00 00 00 00  ....@.0À........
000001D0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000001E0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000001F0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
00000200  31 C0 31 DB 31 C9 31 D2 EB 37 59 88 51 0A BB 7B  1À1Û1É1Ò ë7Y^Q.»{
00000210  1D 80 7C 51 FF D3 EB 39 59 31 D2 88 51 0B 51 50  .€|QÿÓë9Y1Ò^Q.QP
00000220  BB 30 AE 80 7C FF D3 EB 39 59 31 D2 88 51 03 31  »0®€|ÿÓë9Y1Ò^Q.1
00000230  D2 52 51 51 52 FF D0 31 D2 50 B8 FA CA 81 7C FF  ÒRQQRÿÐ1ÒP¸úÊ.|ÿ
00000240  D0 E8 C4 FF FF FF 75 73 65 72 33 32 2E 64 6C 6C  ÐèÄÿÿÿuser32.dll
00000250  4E E8 C2 FF FF FF 4D 65 73 73 61 67 65 42 6F 78  NèÂÿÿÿMessageBox
00000260  41 4E E8 C2 FF FF FF 48 65 79 4E FF FF FF FF 00  ANèÂÿÿÿHeyNÿÿÿÿ.
00000270  00 00 00 FF FF FF FF 00 00 00 00 00 00 00 00 00  ...ÿÿÿÿ.........
00000280  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
00000290  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000002A0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000002B0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000002C0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000002D0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000002E0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000002F0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
```

Then go to the top toolbar, Edit→Copy As→C



Now create a new project in Visual Studio, make a Win32 console project, and make sure it's an empty project. If you need help doing this, see the first tutorial.

Paste the hex you copied as C from HxD. It should look like this.



Now we are going to fill in the main() part of our c program to call this code. It will look like this. Below the picture is the code you can copy and paste.

```
   StartOffset: 00000200, EndOffset: 0000026A, Length: 0000006B */

unsigned char rawData[107] = {
    0x31, 0xC0, 0x31, 0xDB, 0x31, 0xC9, 0x31, 0xD2, 0xEB, 0x37, 0x59, 0x88,
    0x51, 0x0A, 0xBB, 0x7B, 0x1D, 0x80, 0x7C, 0x51, 0xFF, 0xD3, 0xEB, 0x39,
    0x59, 0x31, 0xD2, 0x88, 0x51, 0x0B, 0x51, 0x50, 0xBB, 0x30, 0xAE, 0x80,
    0x7C, 0xFF, 0xD3, 0xEB, 0x39, 0x59, 0x31, 0xD2, 0x88, 0x51, 0x03, 0x31,
    0xD2, 0x52, 0x51, 0x51, 0x52, 0xFF, 0xD0, 0x31, 0xD2, 0x50, 0xB8, 0xFA,
    0xCA, 0x81, 0x7C, 0xFF, 0xD0, 0xE8, 0xC4, 0xFF, 0xFF, 0xFF, 0x75, 0x73,
    0x65, 0x72, 0x33, 0x32, 0x2E, 0x64, 0x6C, 0x6C, 0x4E, 0xE8, 0xC2, 0xFF,
    0xFF, 0xFF, 0x4D, 0x65, 0x73, 0x73, 0x61, 0x67, 0x65, 0x42, 0x6F, 0x78,
    0x41, 0x4E, 0xE8, 0xC2, 0xFF, 0xFF, 0xFF, 0x48, 0x65, 0x79, 0x4E
};

int main()
{

    int (*func) ();            //declare pointer to function that returns an int and takes a void or no args
    func =  (int (*) ())&rawData;  //assign func pointer to address of code, (int (*) () ) is the type cast.
    func();                    //call shellcode

}
```

```
int main()
{
      int (*func) ();
      func =  (int (*) ())&code;
      func();
}
```

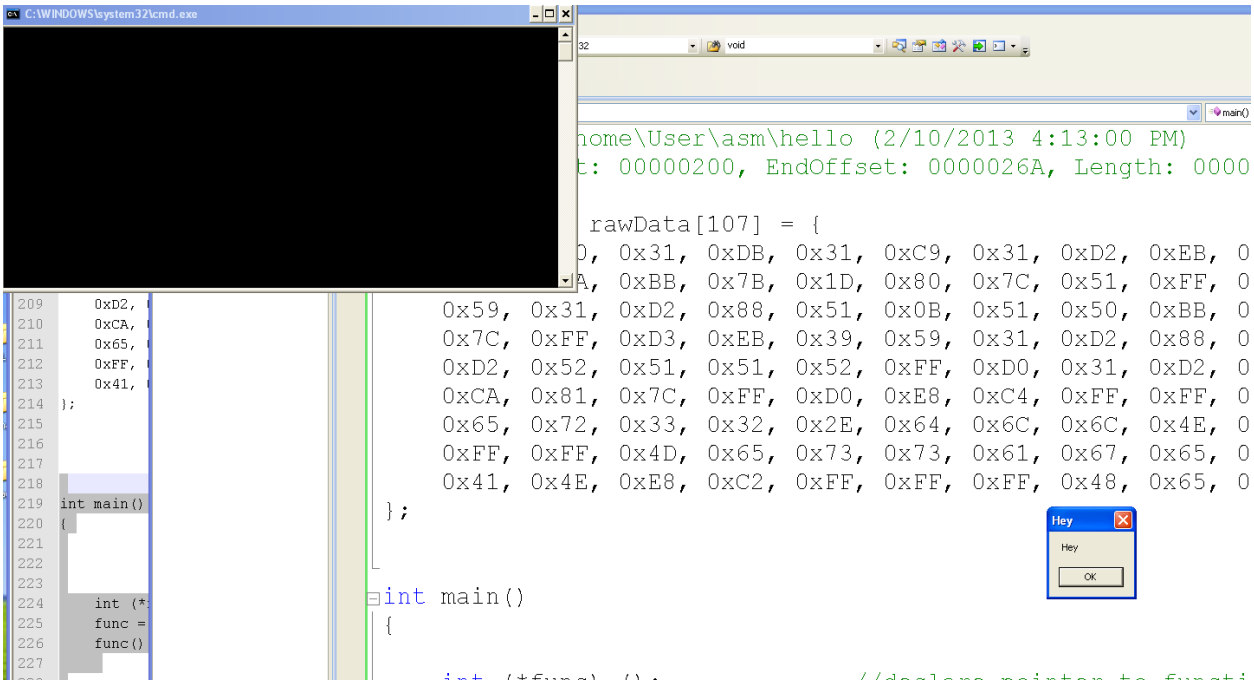
Let's go over what each line is doing.

`int (*func) ()` **This declares a pointer to function that returns an int and takes a void or no args**

`func = (int (*) ())&code;` **This assigns a function pointer to address of code, (int (*) ()) is the type cast.**

`func();` **This calls the function**

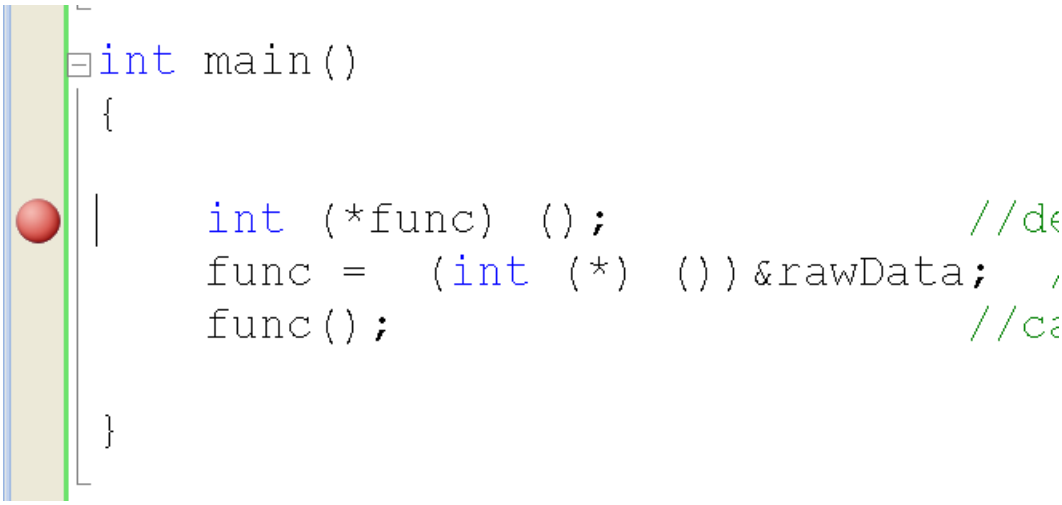
Build it and run it.



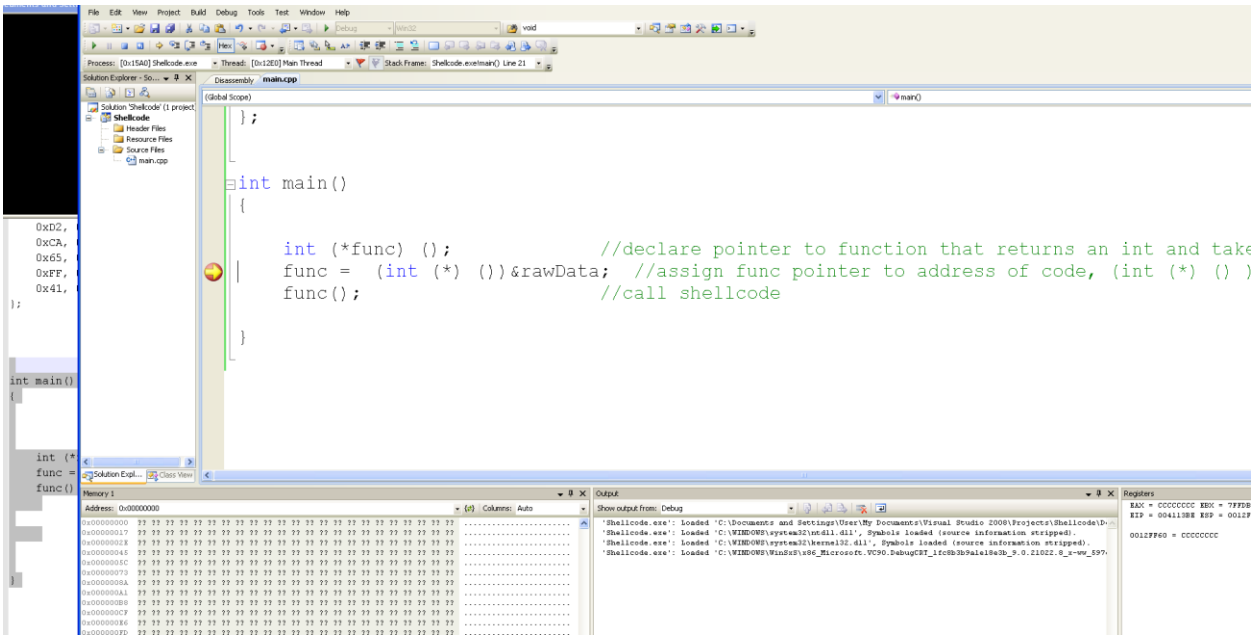
We get another popup box.

Let's use the debugger and step through the code.

Left click the side bar next to int (*func) (); This will place a breakpoint which is indicated by a big red circle.



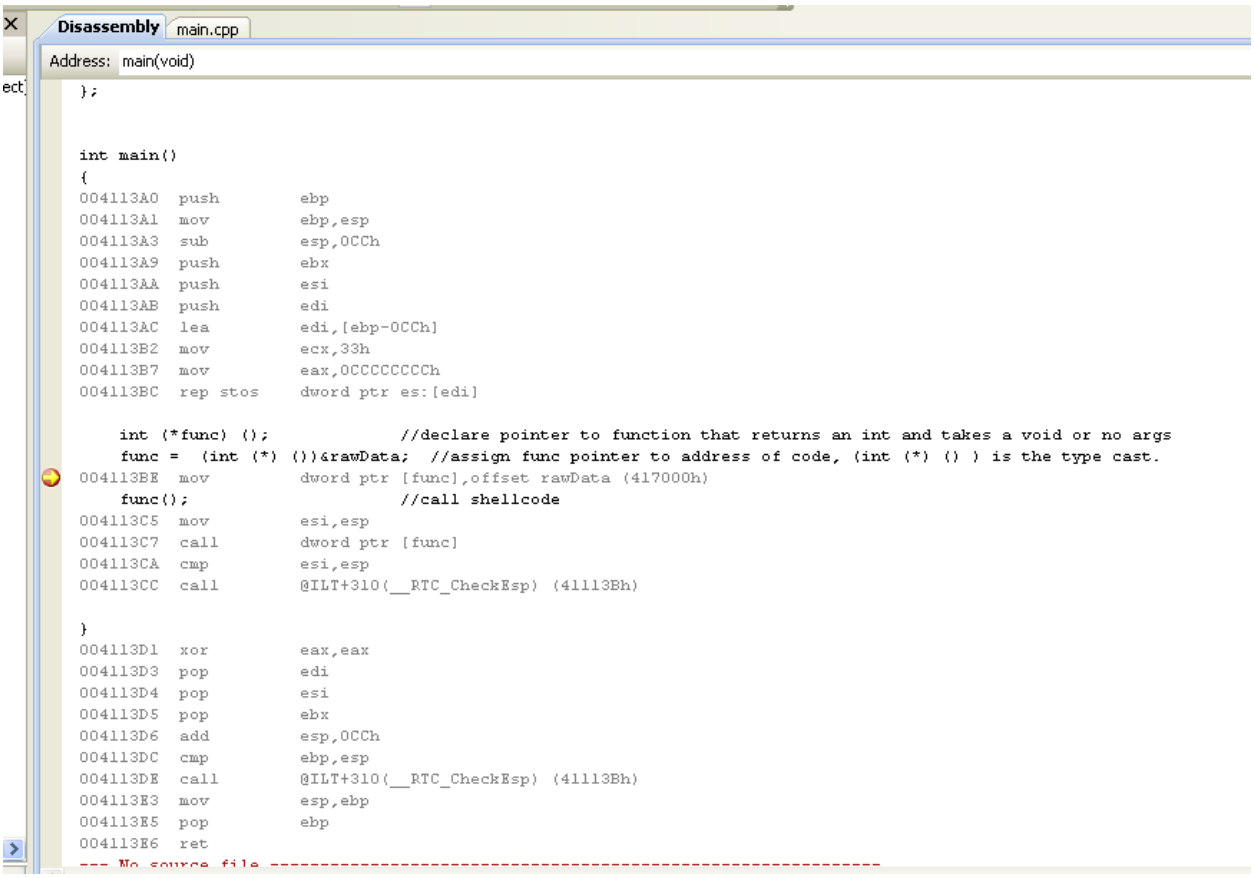
Go up to the top toolbar, Debug→Start Debugging



A tab should open near the top that says disassembly. If this tab does not open, press alt+8 to open it.

Click the disassembly tab. You should now see your c code in bold black, with the assembly code in grey. The c code is acting like comments to the assembly code. The assembly code is actually being executed.

Now to move forward in the code, press F10. This is step over.



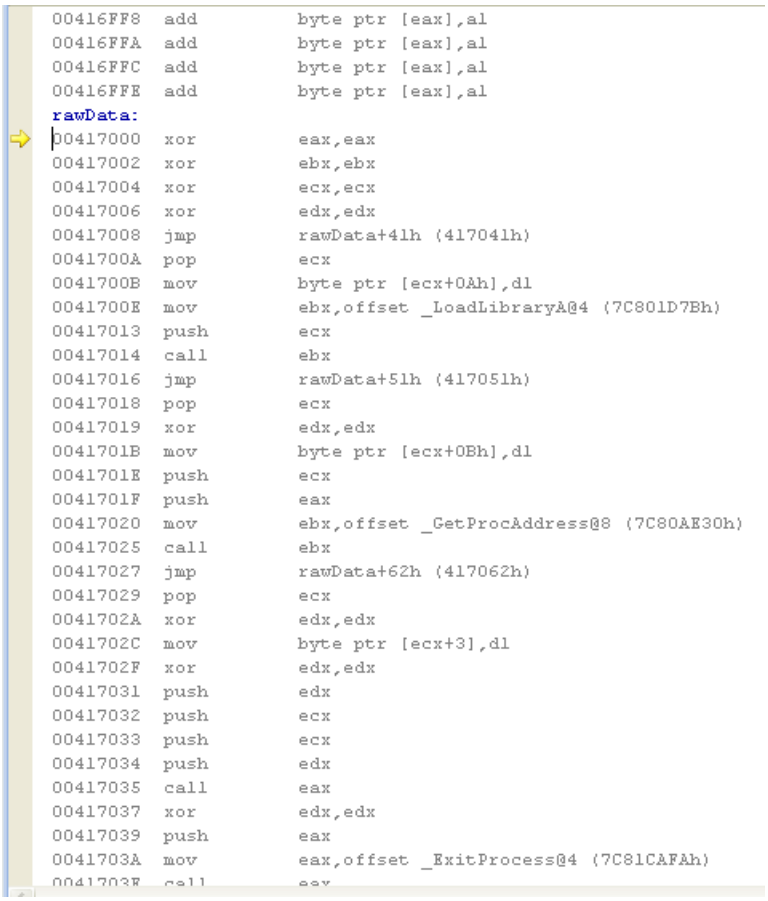
You can press F10 until the pop-up box says hello and the program ends. But we want to see our character array filled with hex code execute.

When you reach the line that says:

Call dword, ptr [func]

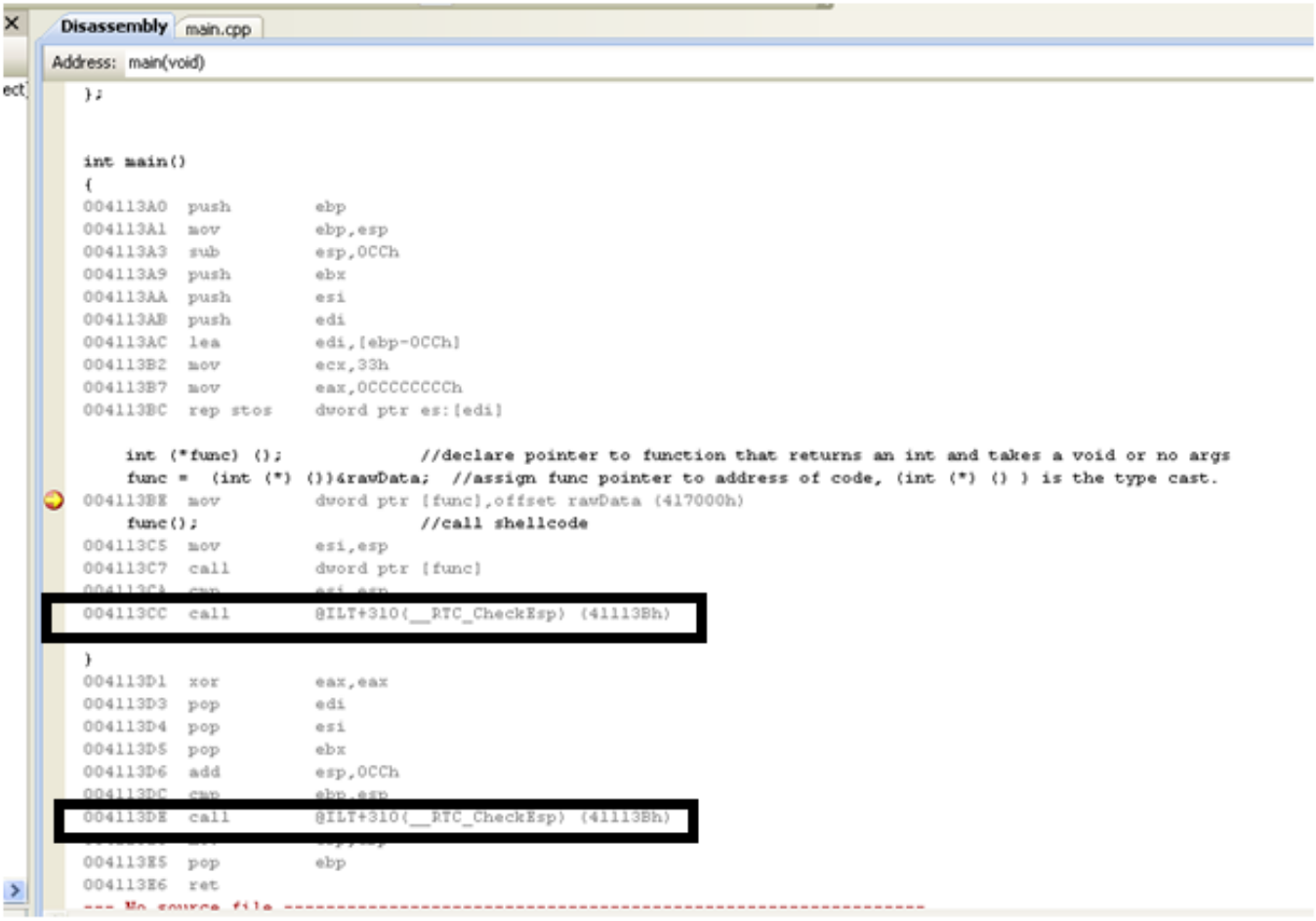
Press F11. This will step into, which means it will follow the assembly into that function.

If you press F11 when the yellow arrow is on the line that says call dword, ptr [func] you will then jump to that code. That should look like this:

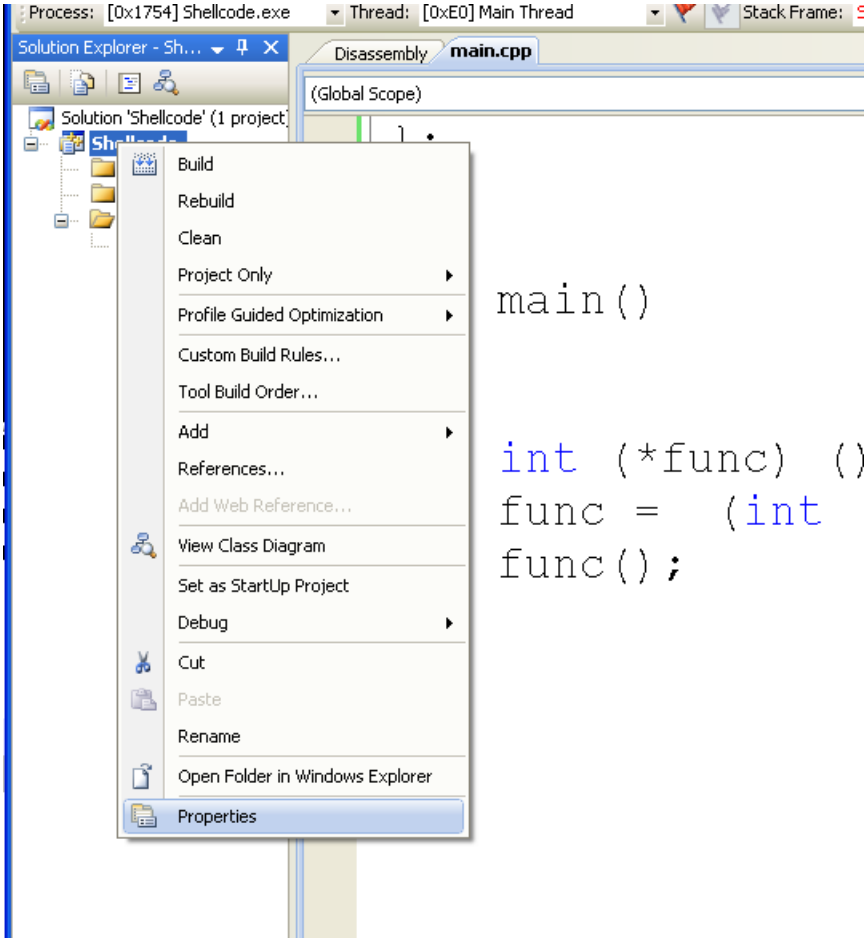


You are now looking at the code then you original assembled using NASM and Cygwin. If has been translated into hex data and entered into our program through the source code.

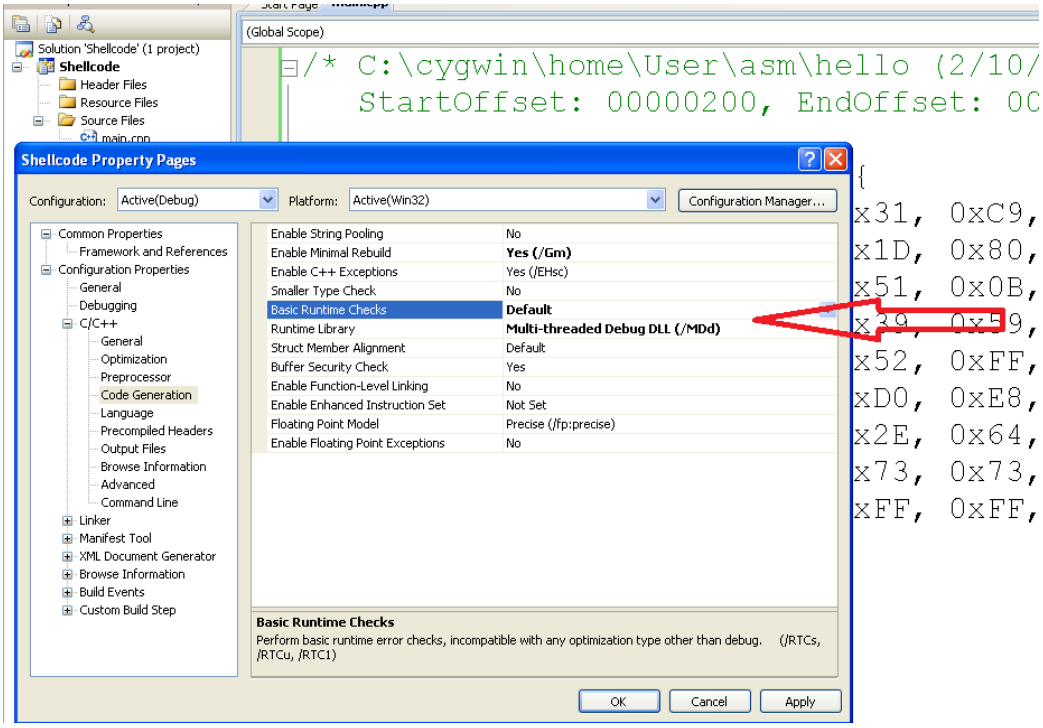
Going back to when we first started debugging. There are a lot of extra assembly instructions in there that we weren't expecting. These are security features added to our program by Microsoft.



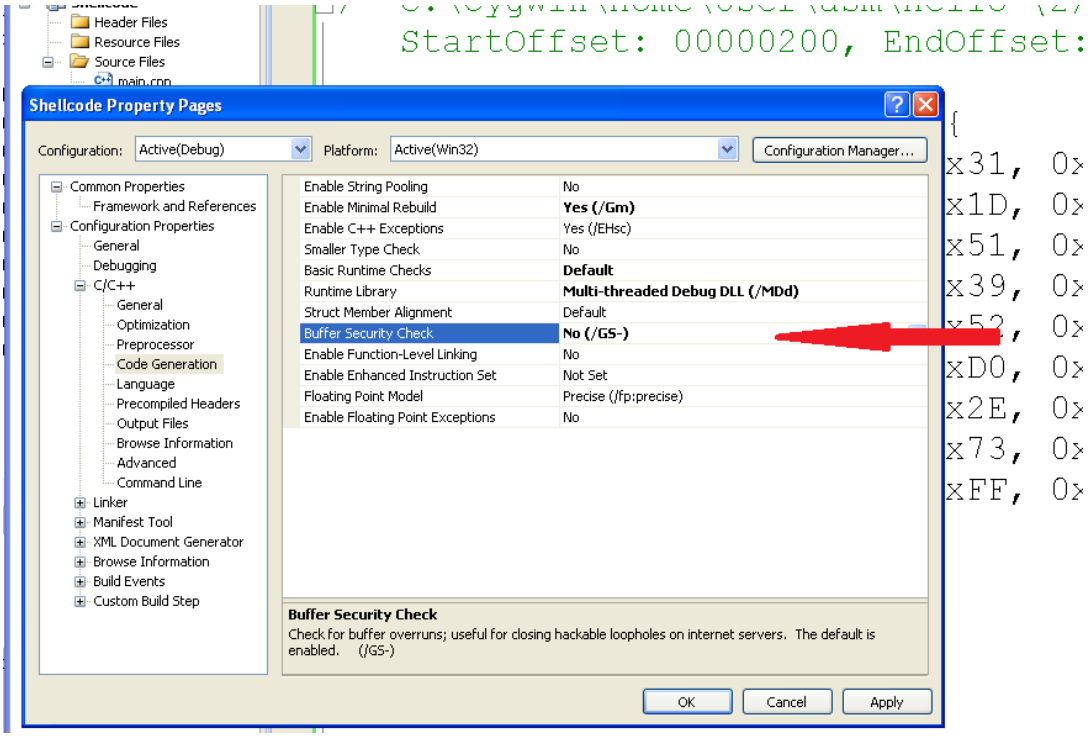
We can remove some of these for the sake of clarity by going to project→properties. Make sure you are no longer debugging.



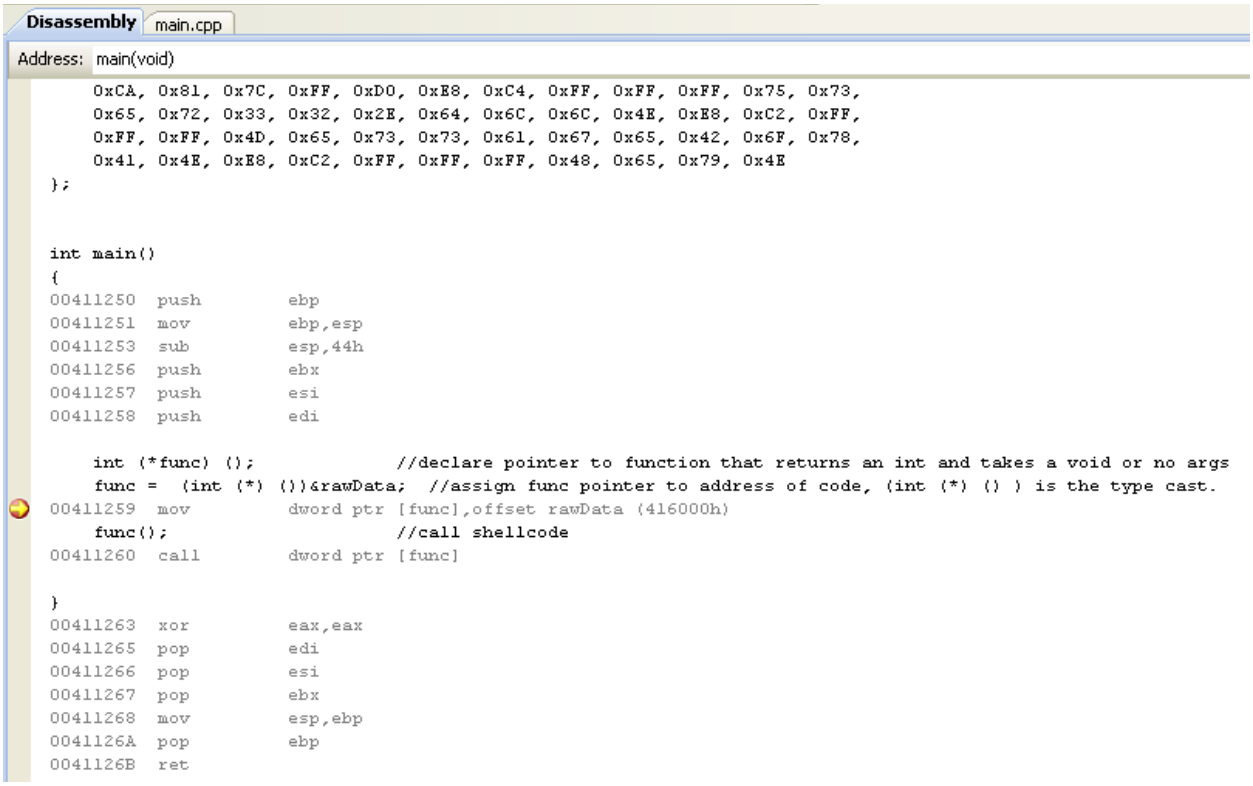
Then go to Configuration Properties→C/C++→Code Generation→Basic Runtime Checks and set it to default.



Also set Buffer Security Check to No.



Now rebuild and start debugging. The assembly should be significantly less cluttered.



There is a repository of shellcode at http://www.shell-storm.org/shellcode/

See what you can get to run on your computer. I will have the third tutorial up shortly that will show how to take control of a vulnerable program and inject shellcode into it.