Assignment 3 Final Write up

E Enterprises Binary Report - Evan Haaland

Executive Summary

I was given a program called challenge 2 to analyze. This program is a Linux program what has the user enter in a pass phrase. If the pass phrase is wrong it says access denied. If the user is able to guess the password it would say access granted. However, in my discovery we can actually get passed the password check without knowing the password.

When looking at the program I saw that there was no debug symbols which made it a bit harder to see the names of certain variables and functions. However, I was able to find the main function which was a massive help. From there I could see that there was another function called *f* that was called. I saw when I put no argument in the program would jump to the end without calling the *f* function. This is a good technique that could confuse someone when looking at it. At first I thought the program did nothing until I dug in a little deeper.

When I started to investigated the *f* function I saw that it was very long. I also noticed that there was no other suspicious functions. This gave me a sign that this could be very important. As I would step through I would see many commands modifying single registers using commands that I have seen in encryption. This made me think that the *f* function would take the passphrase typed in by the user and perform some sort of encryption on it to see if it matches a comparison check in main. When I noticed this my first instinct was to look at main for this comparison.

When I saw the comparison in main I saw that the value it was being compared to was visible and a set arbitrary value. This made me think that I could use this value and put it back through the encryption algorithm in the *f* function to get the passphrase. Luckily, I noticed a vulnerability that made the process much easier. I saw that I could actually set the value of the password check to the value that it needs to be compared to. Once I set that value to the set value I was able to bypass the program and get the access granted method. This was without even knowing the password.

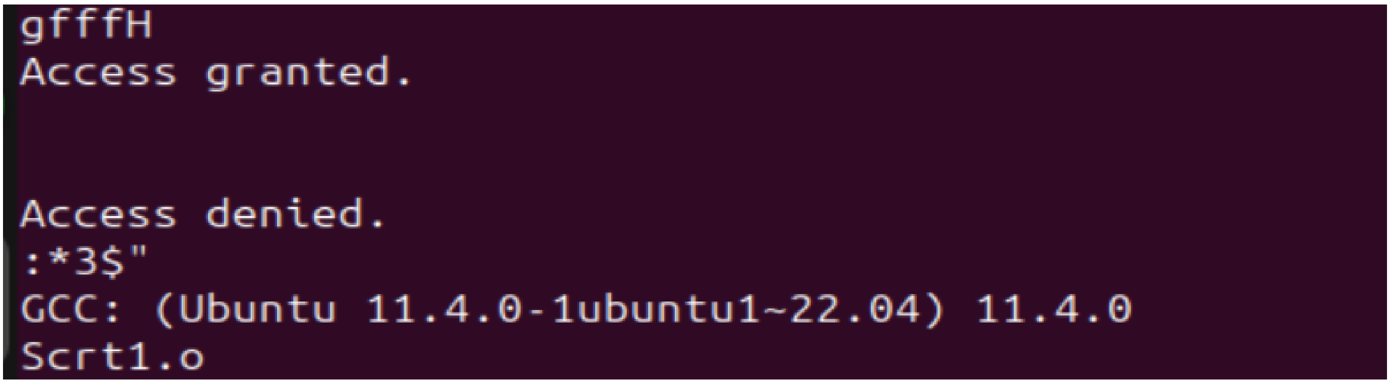
Even though I have cracked the password I wasn't entirely sure if I understood the full functionality of the f function. This is because I saw a lot of interesting commands that I think were put in to throw the reverse engineer off. I noticed that the program would recourse a bunch randomly but it would always end by replacing the return value with a set number. This made me realize that maybe there is no pass phrase that could be used to get access granted.

In hsort, the program is not secure. Anyone with access to decompiler could figure out what they need to bypass the password check. Anyone with a disassembler/debugger can see what they need to set to get the access granted for the answer. Without Obfuscation techniques it was easy to see where the vulnerability was.

Technical Summary

The first thing I did when presented with the binary was running `file challenge2`. This should be that I was looking at an unstripped 64-bit Linux elf file.

I would then run `strings challenge2` to see if there was any strings I could see that would provide insight to what I was looking at. When I did this I was able to see **Access Granted** and **Access Denied**. This made me realize that I could be trying to reverse something with a passcode.

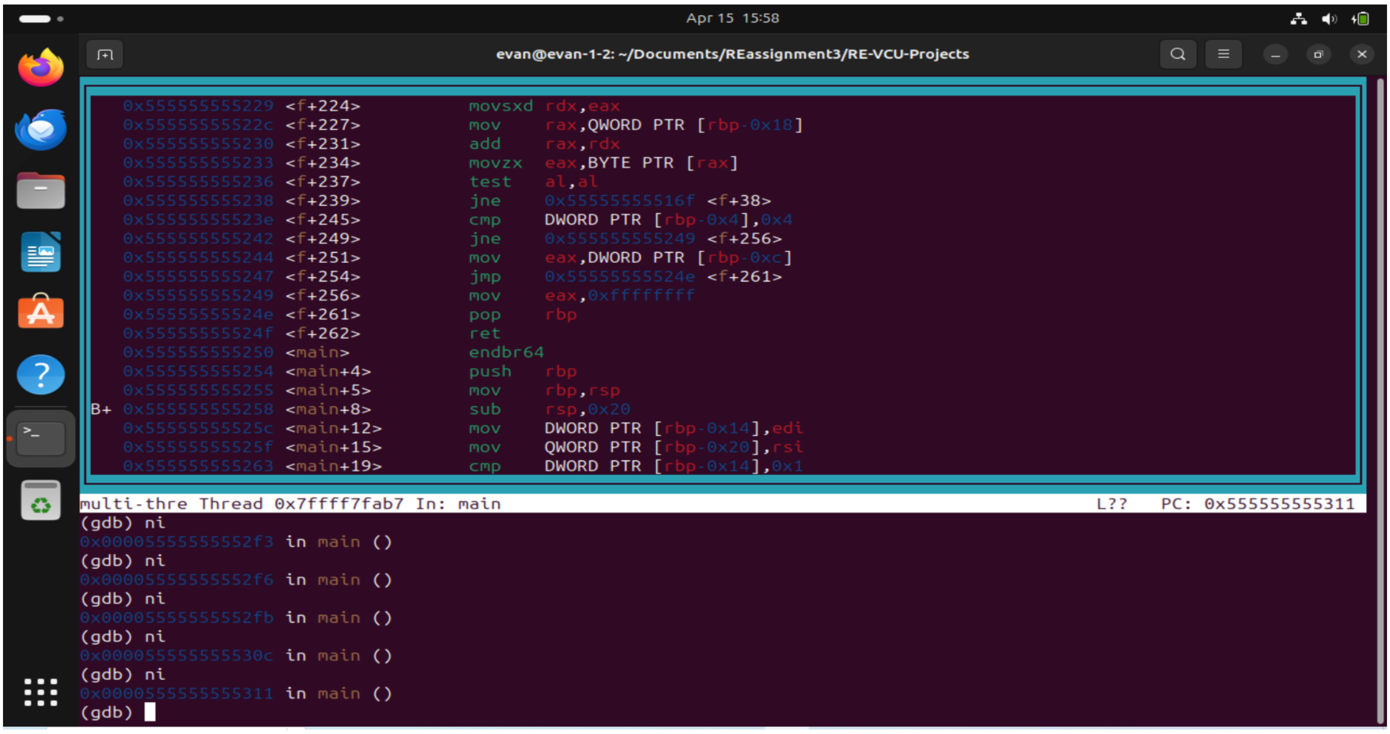


I than ran `objdump -M intel -d challenge2 > challenge2intel.asm` I got an an assembly view of the program and can see the main function as well as a function called *f*. I forget to change this to intel syntax but I was still able to perform some basic static analysis of the binary. By seeing that I could see main and another function that it calls helped me triage past a lot of work. I already had some areas of interest to look at.

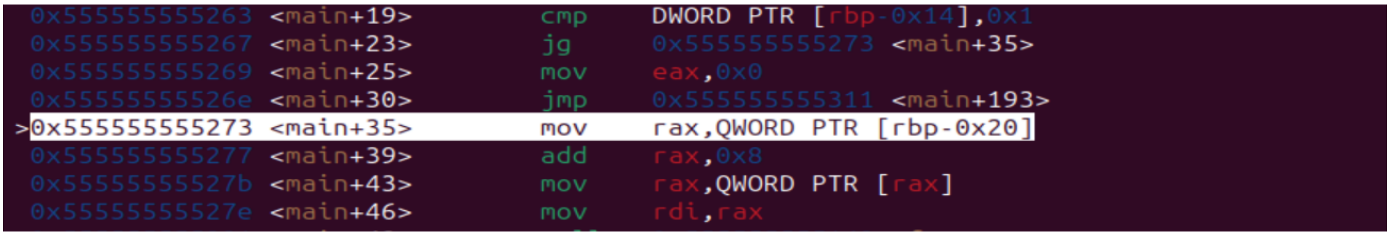
I than decided it was time to perform dynamic analysis with GDB. I started by using `chmod +x challenge2` to get it working as an executable. When I ran it `./challenge2` it would not print any information. I than ran `./challenge2 hello` and I received the **Access denied** message. This proved my theory of it being some sort of password check program.

When I ran the debugger `gdb challenge2` I was able to see that there where no debugging symbols. This made me realize that I might need to take a deeper look at some of the functions being called since they won't have obvious names. I set break points at main and f to see what happens at these functions. `(gdb) break main` `(gdb) break f`.
I needed to look at the disassembly at this function. `(gdb) disassemble`. However, I wanted to find a way to get a more visible way of looking at the assembly step by step. I ran `(gdb)layout asm` and I

was given a way to look at the assembly as I step through.



I would use `(gdb) ni` to step over instructions. I mainly did this as some of the Linux or glibc functions I could skip over as they are not created by the user and a product of the compiler or operating system. I realized that I had to use another command to set arguments for the function. I realized this because there was actually a comparison that would check if the user had any input. This explained why I got no input with no argument.



I used `(gdb) set args hello` to set an argument to something I know would be wrong. This made be able to bypass the cmp check for the necessary amount of arguments. I realized that the next point of investigation for me was the f function call. I saw that the function is called no matter what. I also saw that main would do a comparison to a set value of 0x532 and if it is not equal than it would jump past a bunch of puts() calls. Knowing this I had assumptions that if I bypass that comparison I will be able to view the locked information.

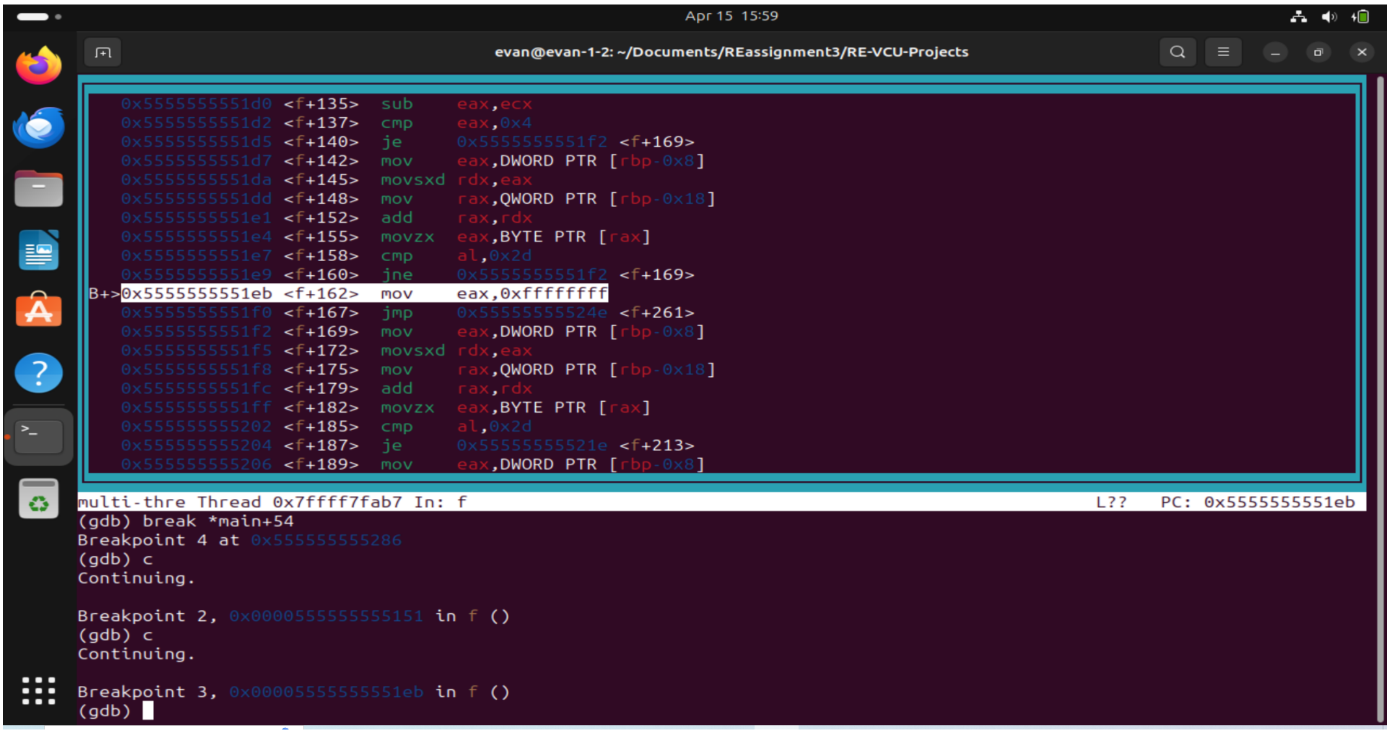
▼ main function code (click to expand)

```
0000000000001250 <main>:
    1250:       f3 0f 1e fa             endbr64
    1254:       55                      push   rbp
    1255:       48 89 e5                mov    rbp,rsp
    1258:       48 83 ec 20             sub    rsp,0x20
    125c:       89 7d ec                mov    DWORD PTR [rbp-0x14],edi
```

```
    125f:	48 89 75 e0          	mov    QWORD PTR [rbp-0x20],rsi
    1263:	83 7d ec 01          	cmp    DWORD PTR [rbp-0x14],0x1
    1267:	7f 0a                	jg     1273 <main+0x23>
    1269:	b8 00 00 00 00       	mov    eax,0x0
    126e:	e9 9e 00 00 00       	jmp    1311 <main+0xc1>
    1273:	48 8b 45 e0          	mov    rax,QWORD PTR [rbp-0x20]
    1277:	48 83 c0 08          	add    rax,0x8
    127b:	48 8b 00             	mov    rax,QWORD PTR [rax]
    127e:	48 89 c7             	mov    rdi,rax
    1281:	e8 c3 fe ff ff       	call   1149 <f>
    1286:	89 45 fc             	mov    DWORD PTR [rbp-0x4],eax
    1289:	81 7d fc 32 05 00 00 	cmp    DWORD PTR [rbp-0x4],0x532
    1290:	75 6b                	jne    12fd <main+0xad>
    1292:	48 8d 05 6f 0d 00 00 	lea    rax,[rip+0xd6f]        # 2008
<_IO_stdin_used+0x8>
    1299:	48 89 c7             	mov    rdi,rax
    129c:	e8 af fd ff ff       	call   1050 <puts@plt>
    12a1:	48 8d 05 78 0d 00 00 	lea    rax,[rip+0xd78]        # 2020
<_IO_stdin_used+0x20>
    12a8:	48 89 c7             	mov    rdi,rax
    12ab:	e8 a0 fd ff ff       	call   1050 <puts@plt>
    12b0:	48 8d 05 b1 0d 00 00 	lea    rax,[rip+0xdb1]        # 2068
<_IO_stdin_used+0x68>
    12b7:	48 89 c7             	mov    rdi,rax
    12ba:	e8 91 fd ff ff       	call   1050 <puts@plt>
    12bf:	48 8d 05 ea 0d 00 00 	lea    rax,[rip+0xdea]        # 20b0
<_IO_stdin_used+0xb0>
    12c6:	48 89 c7             	mov    rdi,rax
    12c9:	e8 82 fd ff ff       	call   1050 <puts@plt>
    12ce:	48 8d 05 1b 0e 00 00 	lea    rax,[rip+0xe1b]        # 20f0
<_IO_stdin_used+0xf0>
    12d5:	48 89 c7             	mov    rdi,rax
    12d8:	e8 73 fd ff ff       	call   1050 <puts@plt>
    12dd:	48 8d 05 4c 0e 00 00 	lea    rax,[rip+0xe4c]        # 2130
<_IO_stdin_used+0x130>
    12e4:	48 89 c7             	mov    rdi,rax
    12e7:	e8 64 fd ff ff       	call   1050 <puts@plt>
    12ec:	48 8d 05 8d 0e 00 00 	lea    rax,[rip+0xe8d]        # 2180
<_IO_stdin_used+0x180>
    12f3:	48 89 c7             	mov    rdi,rax
    12f6:	e8 55 fd ff ff       	call   1050 <puts@plt>
    12fb:	eb 0f                	jmp    130c <main+0xbc>
    12fd:	48 8d 05 bd 0e 00 00 	lea    rax,[rip+0xebd]        # 21c1
```

```
<_IO_stdin_used+0x1c1>
    1304:       48 89 c7                mov    rdi,rax
    1307:       e8 44 fd ff ff          call   1050 <puts@plt>
    130c:       b8 00 00 00 00          mov    eax,0x0
    1311:       c9                      leave
    1312:       c3                      ret
```

When I was stepping through the *f* function I could see alot of interesting information. I saw call such as `shl` `shr` `imul` which were either math or bit manipulation calls. This made me think that the function could be taking the users argument and performing some encryption on it and then checking it matches any hardset value that I could find. I did have some suspicions. I noticed that there were many lines like `MOV eax , 0xffffffff` that were called right before the function left. I did not think much of this until I saw that the next instruction in main when we leave the program sets the value of eax into the DWORD PTR. This made me think that the *f* function could actually be an attempt to generated nonsense code to distract the reverse engineer. I am not sure if there even is a specific passphrase that would give you the answer. By running `(gdb) break *f+167` I was able to set the breakpoint at a specific address. I used different variations of this technique.



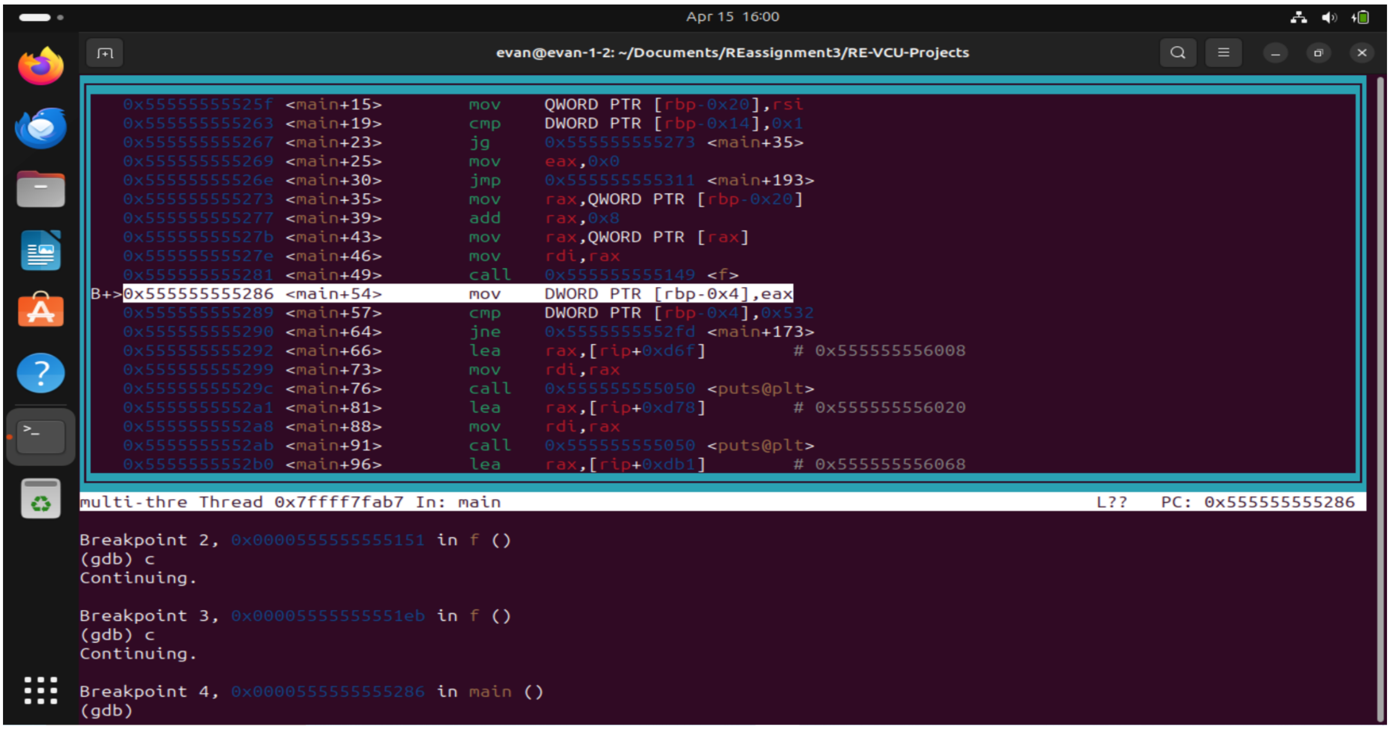
▼ f function code (click to expand)

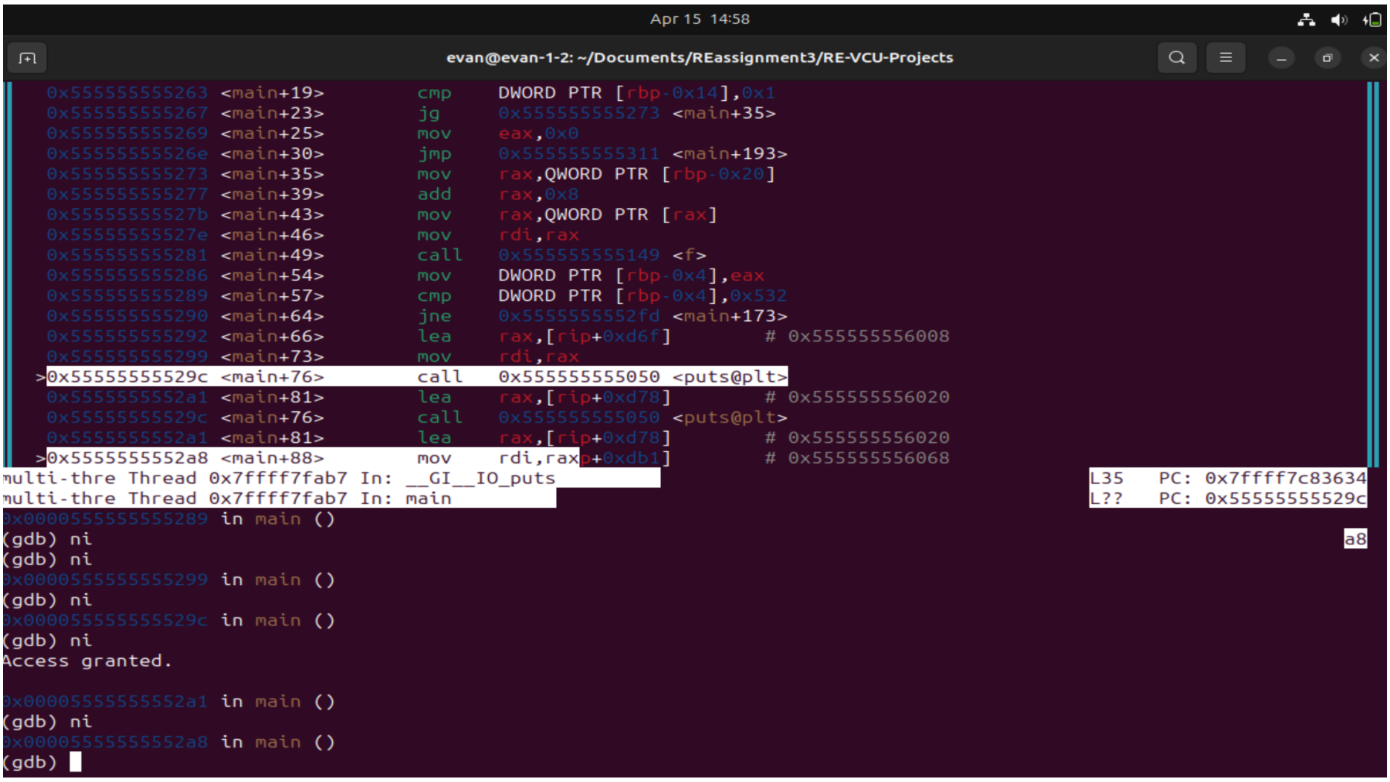
```
0000000000001149 <f>:
    1149:       f3 0f 1e fa             endbr64
    114d:       55                      push   rbp
    114e:       48 89 e5                mov    rbp,rsp
    1151:       48 89 7d e8             mov    QWORD PTR [rbp-0x18],rdi
    1155:       c7 45 f4 00 00 00 00    mov    DWORD PTR [rbp-0xc],0x0
    115c:       c7 45 fc 00 00 00 00    mov    DWORD PTR [rbp-0x4],0x0
    1163:       c7 45 f8 00 00 00 00    mov    DWORD PTR [rbp-0x8],0x0
```

```
116a:   e9 b7 00 00 00          jmp    1226 <f+0xdd>
116f:   8b 55 f8                mov    edx,DWORD PTR [rbp-0x8]
1172:   48 63 c2                movsxd rax,edx
1175:   48 69 c0 67 66 66 66    imul   rax,rax,0x66666667
117c:   48 c1 e8 20             shr    rax,0x20
1180:   d1 f8                   sar    eax,1
1182:   89 d1                   mov    ecx,edx
1184:   c1 f9 1f                sar    ecx,0x1f
1187:   29 c8                   sub    eax,ecx
1189:   89 c1                   mov    ecx,eax
118b:   c1 e1 02                shl    ecx,0x2
118e:   01 c1                   add    ecx,eax
1190:   89 d0                   mov    eax,edx
1192:   29 c8                   sub    eax,ecx
1194:   83 f8 04                cmp    eax,0x4
1197:   75 14                   jne    11ad <f+0x64>
1199:   8b 45 f8                mov    eax,DWORD PTR [rbp-0x8]
119c:   48 63 d0                movsxd rdx,eax
119f:   48 8b 45 e8             mov    rax,QWORD PTR [rbp-0x18]
11a3:   48 01 d0                add    rax,rdx
11a6:   0f b6 00                movzx  eax,BYTE PTR [rax]
11a9:   3c 2d                   cmp    al,0x2d
11ab:   75 3e                   jne    11eb <f+0xa2>
11ad:   8b 55 f8                mov    edx,DWORD PTR [rbp-0x8]
11b0:   48 63 c2                movsxd rax,edx
11b3:   48 69 c0 67 66 66 66    imul   rax,rax,0x66666667
11ba:   48 c1 e8 20             shr    rax,0x20
11be:   d1 f8                   sar    eax,1
11c0:   89 d1                   mov    ecx,edx
11c2:   c1 f9 1f                sar    ecx,0x1f
11c5:   29 c8                   sub    eax,ecx
11c7:   89 c1                   mov    ecx,eax
11c9:   c1 e1 02                shl    ecx,0x2
11cc:   01 c1                   add    ecx,eax
11ce:   89 d0                   mov    eax,edx
11d0:   29 c8                   sub    eax,ecx
11d2:   83 f8 04                cmp    eax,0x4
11d5:   74 1b                   je     11f2 <f+0xa9>
11d7:   8b 45 f8                mov    eax,DWORD PTR [rbp-0x8]
11da:   48 63 d0                movsxd rdx,eax
11dd:   48 8b 45 e8             mov    rax,QWORD PTR [rbp-0x18]
11e1:   48 01 d0                add    rax,rdx
11e4:   0f b6 00                movzx  eax,BYTE PTR [rax]
```

```
    11e7:       3c 2d                   cmp    al,0x2d
    11e9:       75 07                   jne    11f2 <f+0xa9>
    11eb:       b8 ff ff ff ff          mov    eax,0xffffffff
    11f0:       eb 5c                   jmp    124e <f+0x105>
    11f2:       8b 45 f8                mov    eax,DWORD PTR [rbp-0x8]
    11f5:       48 63 d0                movsxd rdx,eax
    11f8:       48 8b 45 e8             mov    rax,QWORD PTR [rbp-0x18]
    11fc:       48 01 d0                add    rax,rdx
    11ff:       0f b6 00                movzx  eax,BYTE PTR [rax]
    1202:       3c 2d                   cmp    al,0x2d
    1204:       74 18                   je     121e <f+0xd5>
    1206:       8b 45 f8                mov    eax,DWORD PTR [rbp-0x8]
    1209:       48 63 d0                movsxd rdx,eax
    120c:       48 8b 45 e8             mov    rax,QWORD PTR [rbp-0x18]
    1210:       48 01 d0                add    rax,rdx
    1213:       0f b6 00                movzx  eax,BYTE PTR [rax]
    1216:       0f be c0                movsx  eax,al
    1219:       01 45 f4                add    DWORD PTR [rbp-0xc],eax
    121c:       eb 04                   jmp    1222 <f+0xd9>
    121e:       83 45 fc 01             add    DWORD PTR [rbp-0x4],0x1
    1222:       83 45 f8 01             add    DWORD PTR [rbp-0x8],0x1
    1226:       8b 45 f8                mov    eax,DWORD PTR [rbp-0x8]
    1229:       48 63 d0                movsxd rdx,eax
    122c:       48 8b 45 e8             mov    rax,QWORD PTR [rbp-0x18]
    1230:       48 01 d0                add    rax,rdx
    1233:       0f b6 00                movzx  eax,BYTE PTR [rax]
    1236:       84 c0                   test   al,al
    1238:       0f 85 31 ff ff ff       jne    116f <f+0x26>
    123e:       83 7d fc 04             cmp    DWORD PTR [rbp-0x4],0x4
    1242:       75 05                   jne    1249 <f+0x100>
    1244:       8b 45 f4                mov    eax,DWORD PTR [rbp-0xc]
    1247:       eb 05                   jmp    124e <f+0x105>
    1249:       b8 ff ff ff ff          mov    eax,0xffffffff
    124e:       5d                      pop    rbp
    124f:       c3                      ret
```

Right before I was planning on trying to reverse the 0x532 through the *f* function I found a huge vulnerability. I noticed that the `mov DWORD PTR [rbp-0x4] , eax` instruction allows me to set the pointer to the contents of eax which I could assign using gdb. This meant I could assign the value of eax to 0x532 and it would be placed into the pointer. I than ran `(gdb) set $eax = 0x532`. Once I ran that I stepped through the function and got the access granted screen and a print out of the VCU logo.





Impact

Having such a vulnerability is very detrimental. Customers are not as secure as they think. Having a data leak would make customers lose trust in us as a company and not continue to buy our products.

With a huge data leak our reputation could be ruined and prevent further contracts coming to our company. Having a user be able to access any forbidden information in such a quick way is very dangerous. I think using methods of obfuscation and encrtyption would make it much more secure. I think if the f function was used to confuse the reverse engineer that is a step in the write direction of anti reversing techniques. I think if we also did something similar to the *f* function by using a encryption algorithm to create a passcode that it would also make it harder to crack. Even if this software doesn't have a pass phrase, with out methods of anti-reversing I was easily able to get through the programs password check.