IRIS CTF 2025 Now this will run on my 486

Useful knowledge

XOR Operation Property

A *B* = *C*
C B = A
C * A = B

MMAP DOCS

MPROTECT DOCS

Tools Used

Detect it Easy
Ghidra
Strings
GDB with PWNDBG

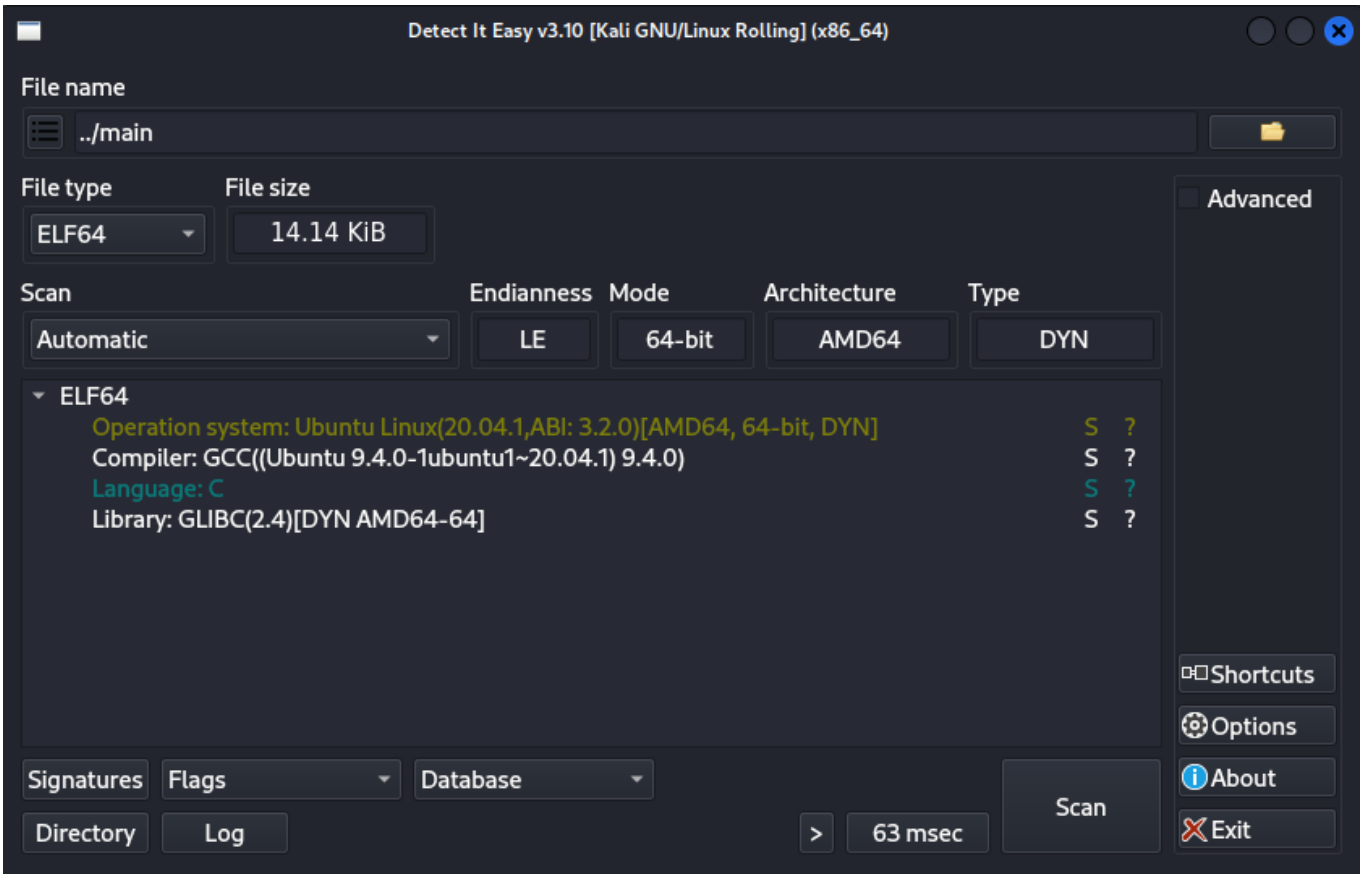
Analysis Process

Step 1. Download Program

https://cdn.2025.irisc.tf/nowthiswillrunonmy486.tar.gz

Step 2. Open File in Detect It Easy

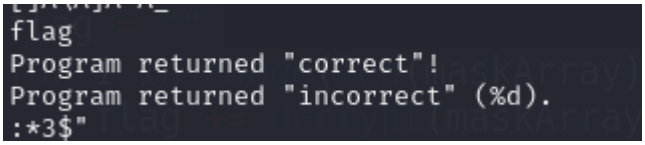
```
die ./main
```

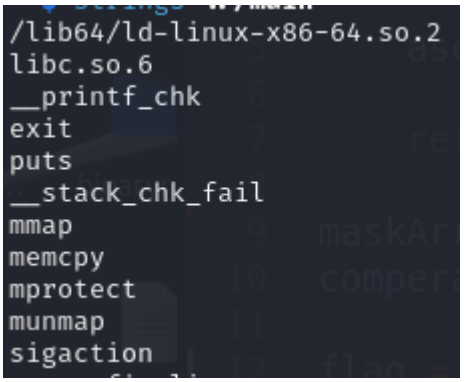


Step 3. Run strings command on the program

```
strings ./main
```

Not too much to see here but we do find somewhat useful strings





Step 4. Open program in ghidra

Opening the file in ghidra we can go to the entry point for our program

```
void processEntry entry(undefined8 param_1,undefined8 param_2)

{
  undefined auStack_8 [8];


__libc_start_main(main,param_2,&stack0x00000008,FUN_00101890,FUN_00101900,para
m_1,auStack_8);
  do {
                    /* WARNING: Do nothing block with infinite loop */
  } while( true );
}
```

Here we can find libc_start_main with the first parameter holding the main function for our program

Main function decompiled with most variable names renamed

```
int main(void)
{
  int returnVal;
  long i;
  undefined8 *arrayPointer;
  undefined8 *arrayPointer2;
  long in_FS_OFFSET;
  byte zero;
  sigaction sigActionObj;
  undefined8 array113 [113];
  long stackCanary;

  zero = 0;
  stackCanary = *(long *)(in_FS_OFFSET + 0x28);
  sigActionObj.sa_flags = 4;
  sigActionObj.__sigaction_handler.sa_handler = sigillActionHandler;
  sigaction(4,&sigActionObj,(sigaction *)0x0);
  arrayPointer = (undefined8 *)&DAT_00102218;
  arrayPointer2 = array113;
  for (i = 0x6f; i != 0; i = i + -1) {
    *arrayPointer2 = *arrayPointer;
    arrayPointer = arrayPointer + (ulong)zero * -2 + 1;
    arrayPointer2 = arrayPointer2 + (ulong)zero * -2 + 1;
  }
  *(undefined *)arrayPointer2 = *(undefined *)arrayPointer;
  size = 889;
  mappedCode = (code *)mmap((void *)0,0x379,0x3,0x22,-1,0);
```

```
  returnVal = 1;
  if (mappedCode != (code *)0xffffffffffffffff) {
    mmapOut2 = mmap((void *)0x0,DAT_00104010,3,34,-1,0);
    if (mmapOut2 != (void *)0xffffffffffffffff) {
      memcpy(mappedCode,array113,size);
      returnVal = mprotect(mappedCode,size,5);
      if (returnVal == -1) {
        returnVal = 1;
      }
      else {
        returnVal = mprotect(mmapOut2,DAT_00104010,3);
        if (returnVal == -1) {
          returnVal = 1;
        }
        else {
          returnVal = (*mappedCode)(0,0,0,0,mmapOut2);
          if (returnVal == 0) {
            puts("Program returned \"correct\"!");
          }
          else {
            __printf_chk(1,"Program returned \"incorrect\"
(%d).\n",returnVal);
          }
          munmap(mappedCode,size);
          munmap(mmapOut2,DAT_00104010);
        }
      }
    }
  }
  if (stackCanary == *(long *)(in_FS_OFFSET + 0x28)) {
    return returnVal;
  }
                    /* WARNING: Subroutine does not return */
  __stack_chk_fail();
}
```

What this program main function does first is initializes a function handler to handle the SIGILL signal sent

`The SIGILL signal is raised when an attempt is made to execute an invalid, privileged, or ill-formed instruction.`

After the function handler has been initialized some operations are done in order to prepare for the call to mmap.

The output of the first mmap call is held in the mappedCode variable which will be called later in main

If all goes well during setup the line of code below calls the mappedCode

```
returnVal = (*mappedCode)(0,0,0,0,mmapOut2);
```

If the value stored in returnVal = 0 we have gotten the correct flag input.

The sigill function handler is a larger function so I wont put the entire function decompilation in to this write up but I will state what it does.

The first thing it does is change the permission on the mapped code to be read/write with the function defined below

```
void setReadWriteMain(void)

{
  int returnCondition;

  returnCondition = mprotect(mappedCode,size,3); // 3 = Read/Write
  if (returnCondition != -1) {
    return;
  }
                    /* WARNING: Subroutine does not return */
  exit(1);
}
```

Then the sigill function handler uses the third parameter passed to it to determine the switch case to take. The switch cases are used to replace the next 8 instructions starting at the point in the mappedCode section we called when we hit a bad instruction

Here is an example of one of the switch cases

```
      case 0xd6:
        switchVar = byteArrayPointer[1];
        bVar1 = byteArrayPointer[2];
        byteArrayPointer[0] = 0x4a;
        byteArrayPointer[1] = 0x8d;
        byteArrayPointer[2] = (byte)((switchVar & 7) << 3) | 4;
        byteArrayPointer[3] = bVar1 & 7;
        byteArrayPointer[4] = 0x90;
        byteArrayPointer[5] = 0x90;
        byteArrayPointer[6] = 0x90;
```

```
        byteArrayPointer[7] = 0x90;
        break;
```

Once the instruction has been replaced by the different switch cases the program changes the permissions on the mappedCode section to read execute with the function definition below

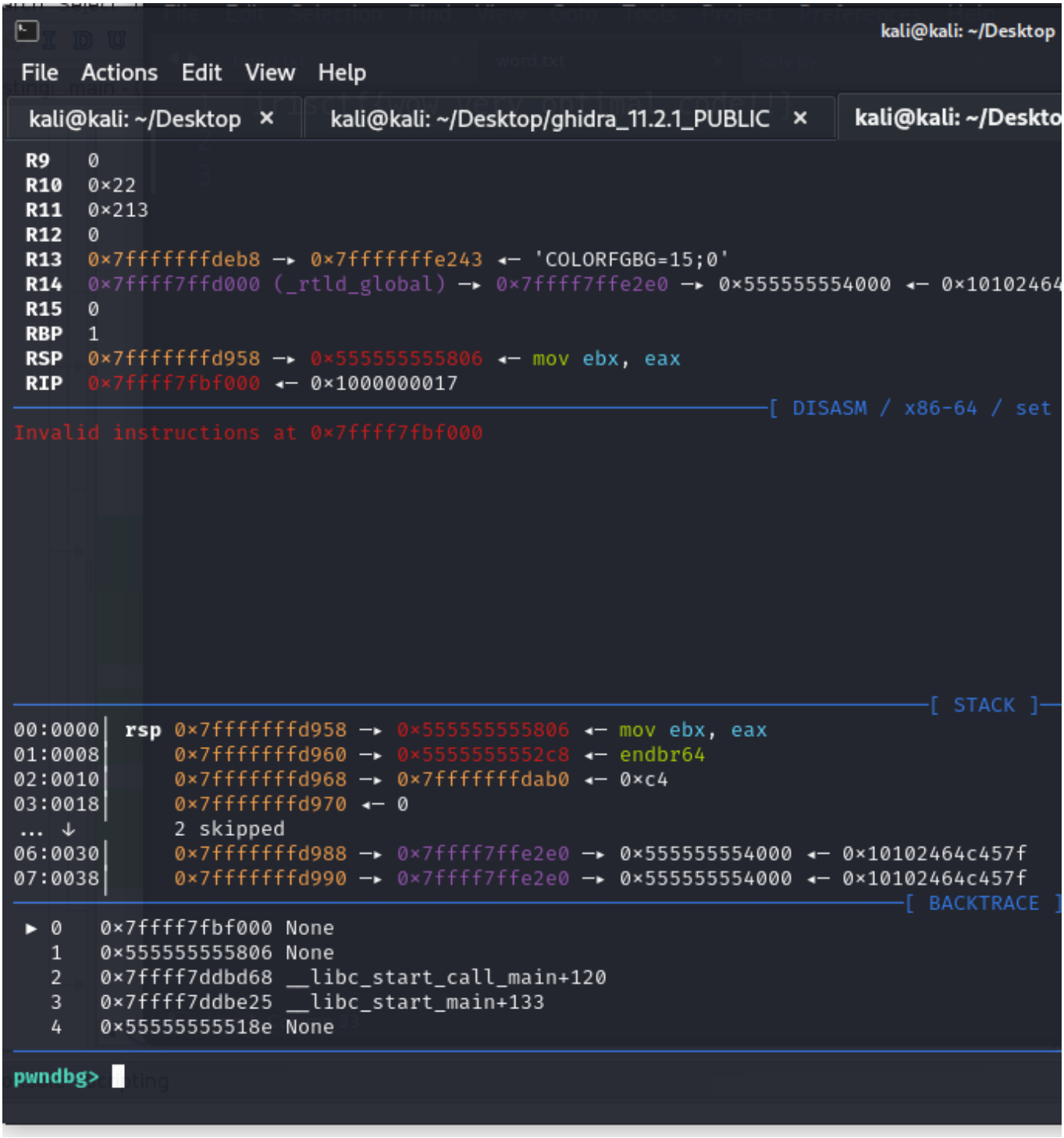
```
void setReadExecMain(void)

{
  int iVar1;

  iVar1 = mprotect(mappedCode,size,5); // 5 = Read/Exec
  if (iVar1 != -1) {
    return;
  }
                    /* WARNING: Subroutine does not return */
  exit(1);
}
```

Once the instructions have been replaced the program returns execution flow to the mappedCode section where the bad instruction was hit

Step 5. Determine flag validity checks

Lets run the program in gdb and see what we can find

When we run the program we hit a bad instruction



Lets examine the bytes at this location

```
pwndbg> x /8i 0x7ffff7fbf000
⇒ 0x7ffff7fbf000:      (bad)
   0x7ffff7fbf001:      add    BYTE PTR [rax],al
   0x7ffff7fbf003:      add    BYTE PTR [rax],dl
   0x7ffff7fbf005:      add    BYTE PTR [rax],al
   0x7ffff7fbf007:      add    BYTE PTR [rdi],dl
   0x7ffff7fbf009:      add    DWORD PTR [rax],eax
   0x7ffff7fbf00b:      data16 ins BYTE PTR es:[rdi],dx
   0x7ffff7fbf00d:      (bad)
pwndbg> x /8bx 0x7ffff7fbf000
0x7ffff7fbf000: 0x17    0x00    0x00    0x00    0x10    0x00    0x00    0x00
pwndbg>
```

We have a bad instruction and then some empty bytes now the sigill signal is sent and the handler function will be ran.

Switch case handler for the bad instruction hit above as you can see 0x17 was hit

```
case 0x17:
    *byteArrayPointer = byteArrayPointer[1] & 7 | 0xb8;
    *(undefined4 *)(byteArrayPointer + 1) = *(undefined4 *)
(byteArrayPointer+3);
    byteArrayPointer[5] = 0x90;
    byteArrayPointer[6] = 0x90;
    byteArrayPointer[7] = 0x90;
    break;
```

If we let the program continue and wait for the next bad instruction we can see what the handler does to the previous section

```
pwndbg> x /8i 0x7ffff7fbf000
   0x7ffff7fbf000:      mov    eax,0x1000
   0x7ffff7fbf005:      nop
   0x7ffff7fbf006:      nop
   0x7ffff7fbf007:      nop
⇒ 0x7ffff7fbf008:      (bad)
   0x7ffff7fbf009:      add    DWORD PTR [rax],eax
   0x7ffff7fbf00b:      data16 ins BYTE PTR es:[rdi],dx
   0x7ffff7fbf00d:      (bad)
pwndbg> x /8bx 0x7ffff7fbf000
0x7ffff7fbf000: 0xb8    0x00    0x10    0x00    0x00    0x90    0x90    0x90
```

As you can see the bad instruction has been replaced with the mov eax, 0x1000 instruction and some trailing nop instructions

If we continue to follow this process and continue to examine the previous memory section we can start to see the operations that actually check the flag validity

Here we can see that a value is taken from DWORD PTR and stored into eax then the value 0xFF is stored in ecx and the values have an and operation performed the result of that operation is stored into eax and then added to edx

```
   0x7ffff7fbf0b0:      mov    eax,DWORD PTR [rax+r8*1]
   0x7ffff7fbf0b4:      nop
   0x7ffff7fbf0b5:      nop
   0x7ffff7fbf0b6:      nop
   0x7ffff7fbf0b7:      nop
   0x7ffff7fbf0b8:      mov    ecx,0xff
   0x7ffff7fbf0bd:      nop
   0x7ffff7fbf0be:      nop
   0x7ffff7fbf0bf:      nop
   0x7ffff7fbf0c0:      and    eax,ecx
   0x7ffff7fbf0c2:      nop
   0x7ffff7fbf0c3:      nop
   0x7ffff7fbf0c4:      nop
   0x7ffff7fbf0c5:      nop
   0x7ffff7fbf0c6:      nop
   0x7ffff7fbf0c7:      nop
   0x7ffff7fbf0c8:      add    edx,eax
```

The DWORD PTR holds the value of the flag given by user input

The instruction above really take each character in the user supplied flag and then and's the character with the value 0xFF and added to a total held in edx

Later down the line if we continue this same method the value in edx is compared with 0xCFF

```
pwndbg> x /24i 0x7ffff7fbf100
   0x7ffff7fbf100:      mov    eax,0xcff
   0x7ffff7fbf105:      nop
   0x7ffff7fbf106:      nop
   0x7ffff7fbf107:      nop
   0x7ffff7fbf108:      cmp    eax,edx
```

This is the first check on our flag. If the total value of the user supplied string with the and operations explained above results in the total 0xCFF we can continue on to further checks on the flag otherwise the program returns that our flag was incorrect

If we follow the same method of allowing the sig ill handler to continue to fix the bad instructions we get to the next check

The next check takes the user given flag 4 characters at a time converts the characters into hex and then applies a mask to it with an XOR operation then compares the value with the expected result. If it is the desired result it goes to the next 4 characters and repeats until the flag has

been validated

```
0x7ffff7fbf130:      mov    eax,DWORD PTR [rcx+r8*1]
0x7ffff7fbf134:      nop
0x7ffff7fbf135:      nop
0x7ffff7fbf136:      nop
0x7ffff7fbf137:      nop
0x7ffff7fbf138:      mov    edx,0xbf51b0d7
0x7ffff7fbf13d:      nop
0x7ffff7fbf13e:      nop
0x7ffff7fbf13f:      nop
0x7ffff7fbf140:      xor    edx,eax
0x7ffff7fbf142:      nop
0x7ffff7fbf143:      nop
0x7ffff7fbf144:      nop
0x7ffff7fbf145:      nop
0x7ffff7fbf146:      nop
0x7ffff7fbf147:      nop
0x7ffff7fbf148:      mov    eax,0xcc38c2be
0x7ffff7fbf14d:      nop
0x7ffff7fbf14e:      nop
0x7ffff7fbf14f:      nop
0x7ffff7fbf150:      cmp    eax,edx
```

If we take the mask and XOR it with the desired output we can reverse the operation and find out the correct 4 characters we need for the flag in reverse order

0xbf51b0d7 ^ 0xcc38c2be = 0x73697269 = 'siri'

The rest of the mask and desired outputs can be recovered if you follow this same method.

Lastly ill provide a python script I wrote in order to solve the challenge

Example Wrong Input

```
┌──(kali㉿kali)-[~/Desktop]
└─$ ./main
flag? blahblah
Program returned "incorrect" (1).
```

Example Correct Input

```
└─$ ./main
flag? irisctf{wow_very_optimal_code!!}
Program returned "correct"!
```

Solution Script

```
def decrypt(input_value, target_value):
        hex_value = input_value ^ target_value
        bytes_value = hex_value.to_bytes(4, byteorder='big')

        ascii_string = bytes_value.decode('ascii')
```

```
        return ascii_string

maskArray =
[0xbf51b0d7,0x75cc547b,0x4f0fd83a,0xa2117744,0xecd0cec6,0x2e19f9fa,0x32ea83d9,
0xe5eb61e0]
comperativeArray =
[0xcc38c2be,0xeaa2018,0x1078b74d,0xdb631232,0x98a0a199,0x42789493,0x5685e086,0
x98ca4085]

flag = ""
for i in range(len(maskArray)):
        flag += decrypt(maskArray[i],comperativeArray[i])[::-1]

print(flag)
```