CRT Library Removal & Malware Compiling

Introduction

Up until this module, all of the code projects were compiled either using the *Release* or *Debug* option in Visual Studio. It is important for malware developers to understand the difference between the Release and Debug compilation options in Visual Studio, as well as the implications of changing the default compiler settings. Modifying Visual Studio's compiler settings can have changes on the produced binary such as reducing the size or lowering entropy.

Release vs Debug Options

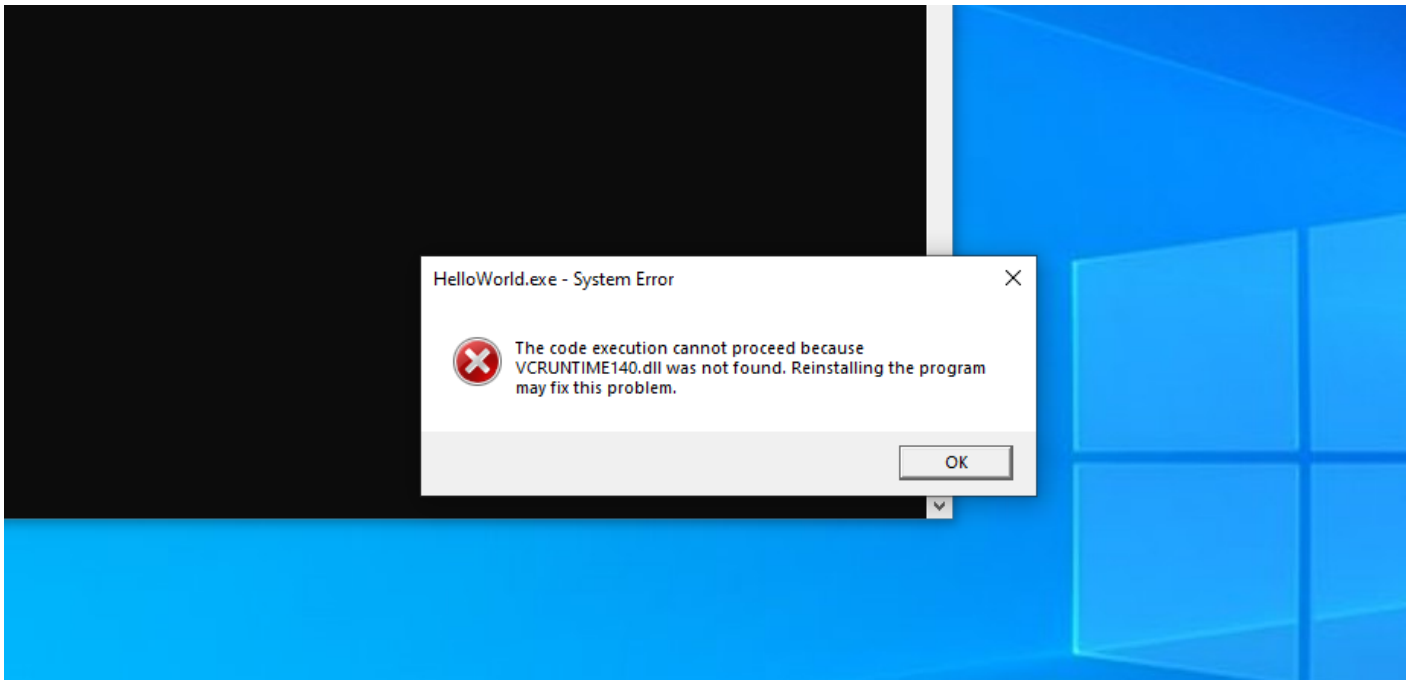
Both "Release" and "Debug" build configurations determine how a program is compiled and executed with each option serving a different purpose and offering distinct features. The most important differences between the two options are shown below.

- **Performance** - The Release build option is faster than that of the Debug. Some building optimizations are enabled in release mode that is disabled in Debug mode.
- **Debugging** - Debugging applications generated by the Debug build configuration is made easier because building optimizations are disabled in this mode, making code easier to debug. Furthermore, the Debug configuration generates Debug Symbol files (.pdb) which contain information about the source code compiled. This enables debuggers to display additional information such as variables, functions and line numbers.
- **Deployment** - The Release version of the application is deployed to users due to its increased compatibility with their machines, unlike the Debug version, which typically requires additional dynamic link libraries (DLLs) that are only available with Visual Studio, thus making Debug applications compatible only with machines that have Visual Studio installed.
- **Exception handling** - In Debug build configuration, Visual Studio can pause execution and show an error message as a message box when an exception is thrown, specifying the variable's name or line number that caused the stack corruption, for example. Such exceptions may cause the program to crash if compiled in Release mode.

Default Compiler Settings

Based on the previous points, the Release option is favorable over the Debug option. With that said, the Release option still has several problems.

- **Compatibility** - Some applications using the Release option can still result in errors similar to the one below if the target machine does not have Visual Studio installed.

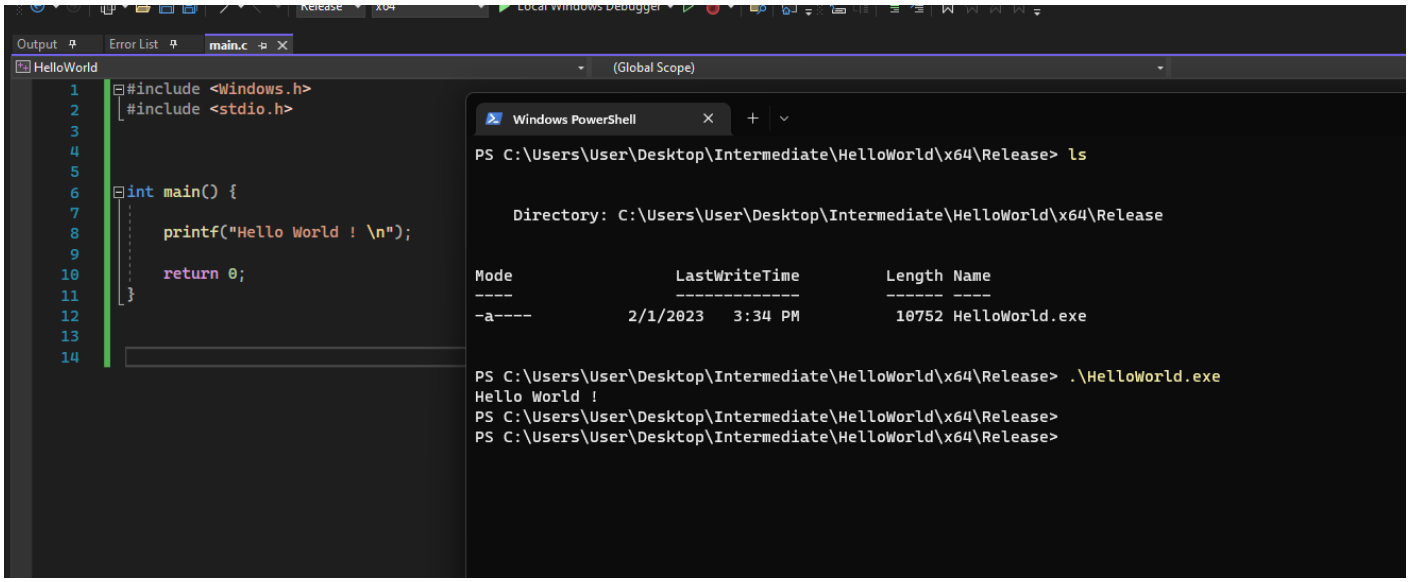


- **CRT Imported Functions** - Several unresolved functions are present in the IAT which cannot be resolved using approaches such as API Hashing. These functions are imported from the CRT library, which will be explained later. For now, it is sufficient to understand that there are several unused imported functions in any application generated by Visual Studio's default compiler settings. As an example, the IAT of a 'Hello World' program should only import information regarding the `printf` function, however, it is importing the following functions (output is truncated due to the size).

```
PS C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release> dumpbin.exe /IMPORTS .\HelloWorld.exe
Microsoft (R) COFF/PE Dumper Version 14.32.31332.0
Copyright (C) Microsoft Corporation.  All rights reserved.


Dump of file .\HelloWorld.exe

File Type: EXECUTABLE IMAGE

  Section contains the following imports:

    VCRUNTIME140.dll
             140002080 Import Address Table
             1400029F8 Import Name Table
                     0 time date stamp
                     0 Index of first forwarder reference

                         1C __current_exception_context
                         1B __current_exception
                          8 __C_specific_handler
                         3E memset
                         3C memcpy

    api-ms-win-crt-stdio-l1-1-0.dll
             140002178 Import Address Table
             140002AF0 Import Name Table
                     0 time date stamp
                     0 Index of first forwarder reference

                          3 __stdio_common_vfprintf
                          0 __acrt_iob_func
                          1 __p__commode
                         54 _set_fmode

    api-ms-win-crt-runtime-l1-1-0.dll
             1400020E0 Import Address Table
             140002A58 Import Name Table
                     0 time date stamp
                     0 Index of first forwarder reference

                         15 _c_exit
                         67 terminate
                         40 _seh_filter_exe
                         42 _set_app_type
                         3C _register_onexit_function
                         1E _crt_atexit
                         16 _cexit
                          5 __p__argv
```

```
api-ms-win-crt-locale-l1-1-0.dll
         1400020C0 Import Address Table
         140002A38 Import Name Table
                 0 time date stamp
                 0 Index of first forwarder reference

                       8 _configthreadlocale

api-ms-win-crt-heap-l1-1-0.dll
         1400020B0 Import Address Table
         140002A28 Import Name Table
                 0 time date stamp
                 0 Index of first forwarder reference

                      16 _set_new_mode

KERNEL32.dll
         140002000 Import Address Table
         140002978 Import Name Table
                 0 time date stamp
                 0 Index of first forwarder reference

                   225 GetCurrentThreadId
                   4DC RtlLookupFunctionEntry
                   4E3 RtlVirtualUnwind
                   5C0 UnhandledExceptionFilter
                   57F SetUnhandledExceptionFilter
                   220 GetCurrentProcess
                   281 GetModuleHandleW
                   385 IsDebuggerPresent
                   36F InitializeSListHead
                   2F3 GetSystemTimeAsFileTime
                   4D5 RtlCaptureContext
                   221 GetCurrentProcessId
                   452 QueryPerformanceCounter
                   38C IsProcessorFeaturePresent
                   59E TerminateProcess
```

- **Size** - The generated files are often bigger than they should be due to the default compiler optimizations. For example, the following `Hello World` program is around 11kb.



- **Debugging Information** - Using the Release option can still include debugging-related information and other strings that can be used by security solutions to create static signatures. The images below show the output of executing `Strings.exe` on the `Hello World` program (output is truncated due to the size).

```
PS C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release> strings.exe .\HelloWorld.exe

Strings v2.54 - Search for ANSI and Unicode strings in binary images.
Copyright (C) 1999-2021 Mark Russinovich
Sysinternals - www.sysinternals.com
```

```
t$0H
@UH
@UH
Hello World !
RSDS
C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release\HelloWorld.pdb
GCTL
.text$mn
.text$mn$00
.text$x
.idata$5
```

```
GetCurrentProcessId
GetCurrentThreadId
GetSystemTimeAsFileTime
InitializeSListHead
IsDebuggerPresent
GetModuleHandleW
KERNEL32.dll
memcpy
<?xml version='1.0' encoding='UTF-8' standalone='yes'?>
<assembly xmlns='urn:schemas-microsoft-com:asm.v1' manifestVersion='1.0'>
  <trustInfo xmlns="urn:schemas-microsoft-com:asm.v3">
    <security>
      <requestedPrivileges>
        <requestedExecutionLevel level='asInvoker' uiAccess='false' />
      </requestedPrivileges>
    </security>
  </trustInfo>
</assembly>
PS C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release>
```

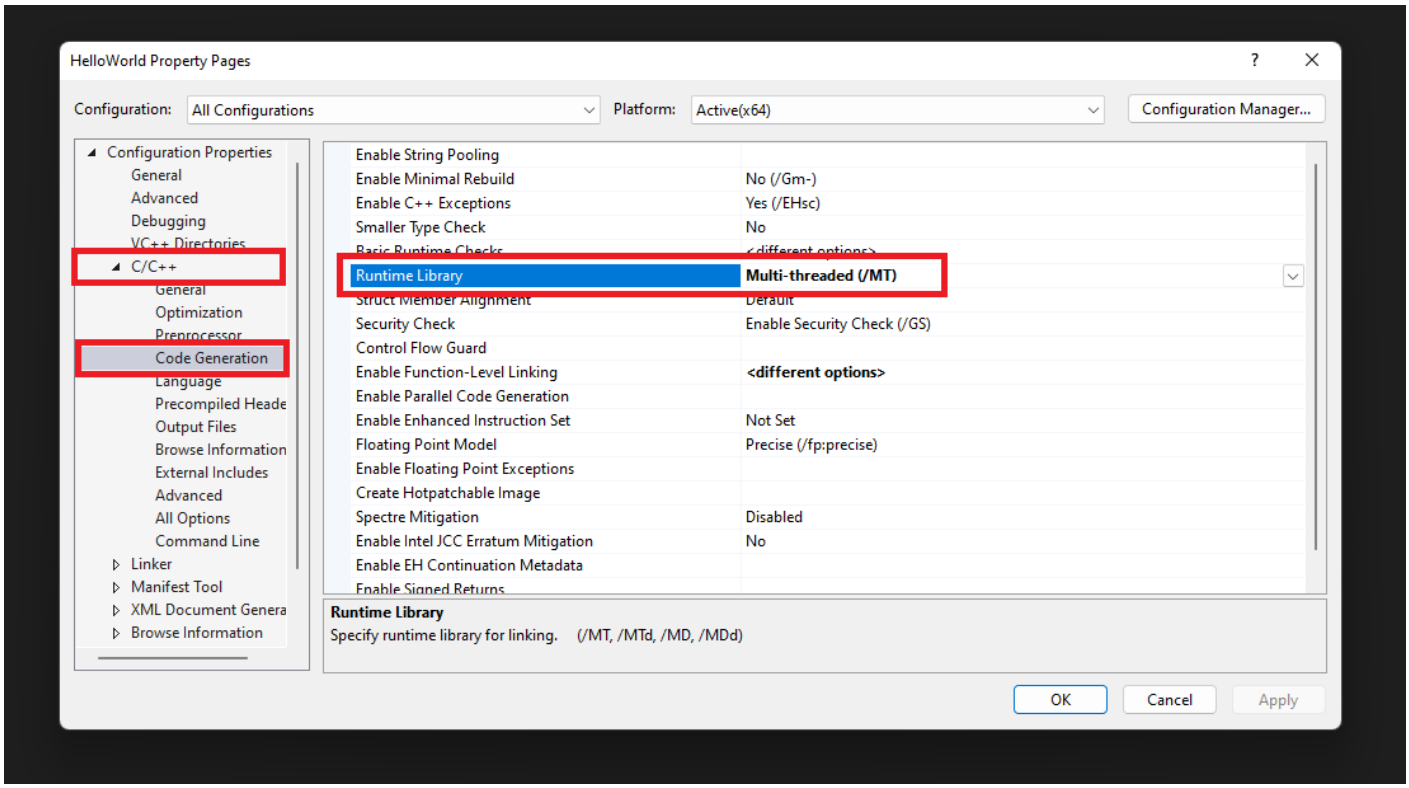
The CRT library

The CRT library, also known as the *Microsoft C Run-Time Library*, is a set of low-level functions and macros that provide a foundation for standard C and C++ programs. It includes functions for memory management (e.g. `malloc`, `memset` and `free`), string manipulation (e.g. `strcpy` and `strlen`) and I/O functions (e.g. `printf`, `wprintf` and `scanf`).

The CRT library DLLs are named `vcruntimeXXX.dll` where XXX is the version number of the CRT library used. There are also DLLs such as `api-ms-win-crt-stdio-l1-1-0.dll`, `api-ms-win-crt-runtime-l1-1-0.dll` and `api-ms-win-crt-locale-l1-1-0.dll` that are also related to the CRT library. Each DLL serves a particular purpose and exports several functions. These DLLs are linked by the compiler at compile time and therefore are found in the IAT of the generated programs.

Solving Compatibility Issues

By default, when compiling an application, the *Runtime Library* option in Visual Studio is set to "Multi-threaded DLL (/MD)". With this option, the CRT Library DLLs are linked dynamically which means they are loaded at runtime. This creates the compatibility issues previously mentioned. To solve these issues, set the Runtime Library option to "Multi-threaded (/MT)", as shown below.



Multi-threaded (/MT)

The Visual Studio compiler can be made to link CRT functions statically by selecting the "Multi-threaded (/MT)" option. This results in functions such as `printf` being directly represented in the generated program, rather than imported from CRT library DLLs. Note that this will increase the size of the final binary and adds more WinAPIs to the IAT, although it removes the CRT library DLLs.

Using the "Multi-threaded (/MT)" option to compile the `Hello World` program results in the following IAT.

```
PS C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release> dumpbin.exe /IMPORTS .\HelloWorld.exe
Microsoft (R) COFF/PE Dumper Version 14.32.31332.0
Copyright (C) Microsoft Corporation.  All rights reserved.


Dump of file .\HelloWorld.exe

File Type: EXECUTABLE IMAGE

  Section contains the following imports:

    KERNEL32.dll
             140013000 Import Address Table
             14001C8F0 Import Name Table
                     0 time date stamp
                     0 Index of first forwarder reference

                         4D5 RtlCaptureContext
                         4DC RtlLookupFunctionEntry
                         4E3 RtlVirtualUnwind
                         5C0 UnhandledExceptionFilter
                         57F SetUnhandledExceptionFilter
                         220 GetCurrentProcess
                         59E TerminateProcess
                         38C IsProcessorFeaturePresent
                         452 QueryPerformanceCounter
                         221 GetCurrentProcessId
                         225 GetCurrentThreadId
                         2F3 GetSystemTimeAsFileTime
                         36F InitializeSListHead
                         385 IsDebuggerPresent
                         2DA GetStartupInfoW
                         281 GetModuleHandleW
                         4E2 RtlUnwindEx
                         26A GetLastError
                         541 SetLastError
                         138 EnterCriticalSection
                         3C4 LeaveCriticalSection
                         114 DeleteCriticalSection
                         36B InitializeCriticalSectionAndSpinCount
                         5B0 TlsAlloc
                         5B2 TlsGetValue
                         5B3 TlsSetValue
                         5B1 TlsFree
                         1B4 FreeLibrary
                         2B8 GetProcAddress
                         3CA LoadLibraryExW
                         468 RaiseException
                         2DC GetStdHandle
                         625 WriteFile
```

The binary becomes considerably larger as well, as shown below.

```
PS C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release> ls


    Directory: C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release


Mode                 LastWriteTime         Length Name
----                 -------------         ------ ----
-a----          2/1/2023   4:41 PM         124928 HelloWorld.exe


PS C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release> .\HelloWorld.exe
Hello World !
PS C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release>
```

CRT Library & Debugging

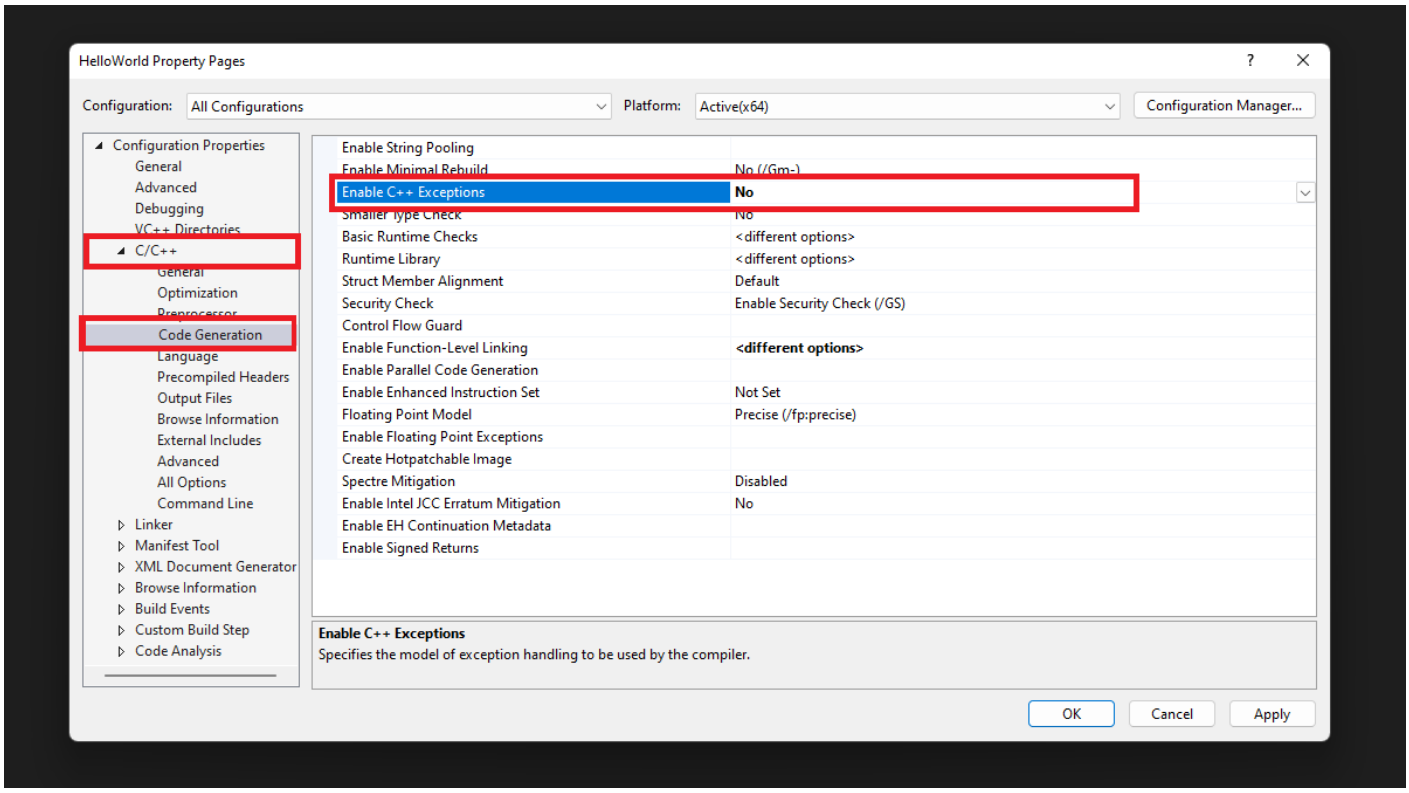
After removing the CRT Library, the program can only be compiled in Release mode. This makes it more difficult to debug the code. Therefore, it is recommended that the removal of the CRT Library is only done after debugging and development are complete.

Additional Compiler Changes

The previous sections demonstrated how to statically link the CRT library. However, the ideal solution would be to avoid relying on the CRT library both statically and dynamically, as this can lead to a reduction in the binary size, as well as the removal of unnecessary imported functions and debug information. To accomplish this, several Visual Studio compilation options must be modified.

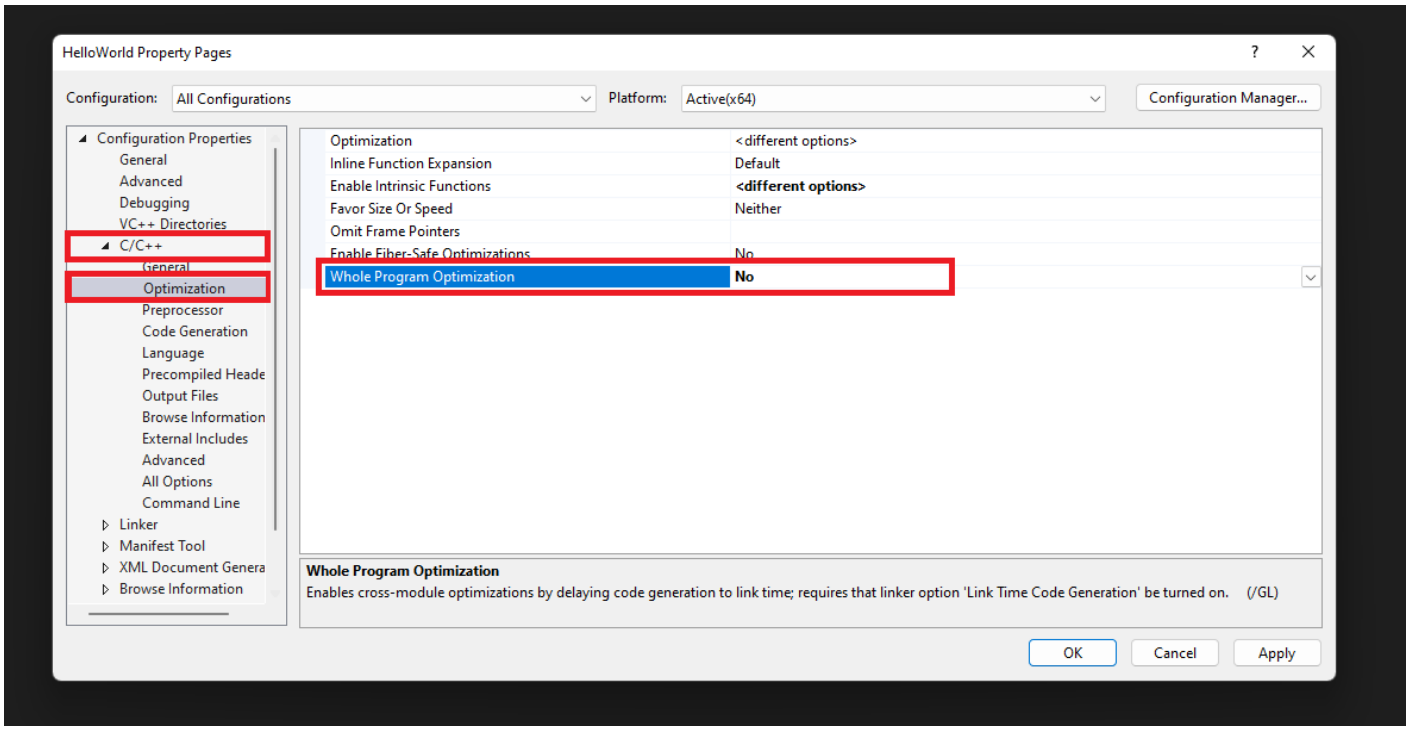
Disable C++ Exceptions

The *Enable C++ Exceptions* option is used to generate code to correctly propagate exceptions thrown by the code, however, as the CRT Library is no longer linked, this option is not necessary and should be disabled.



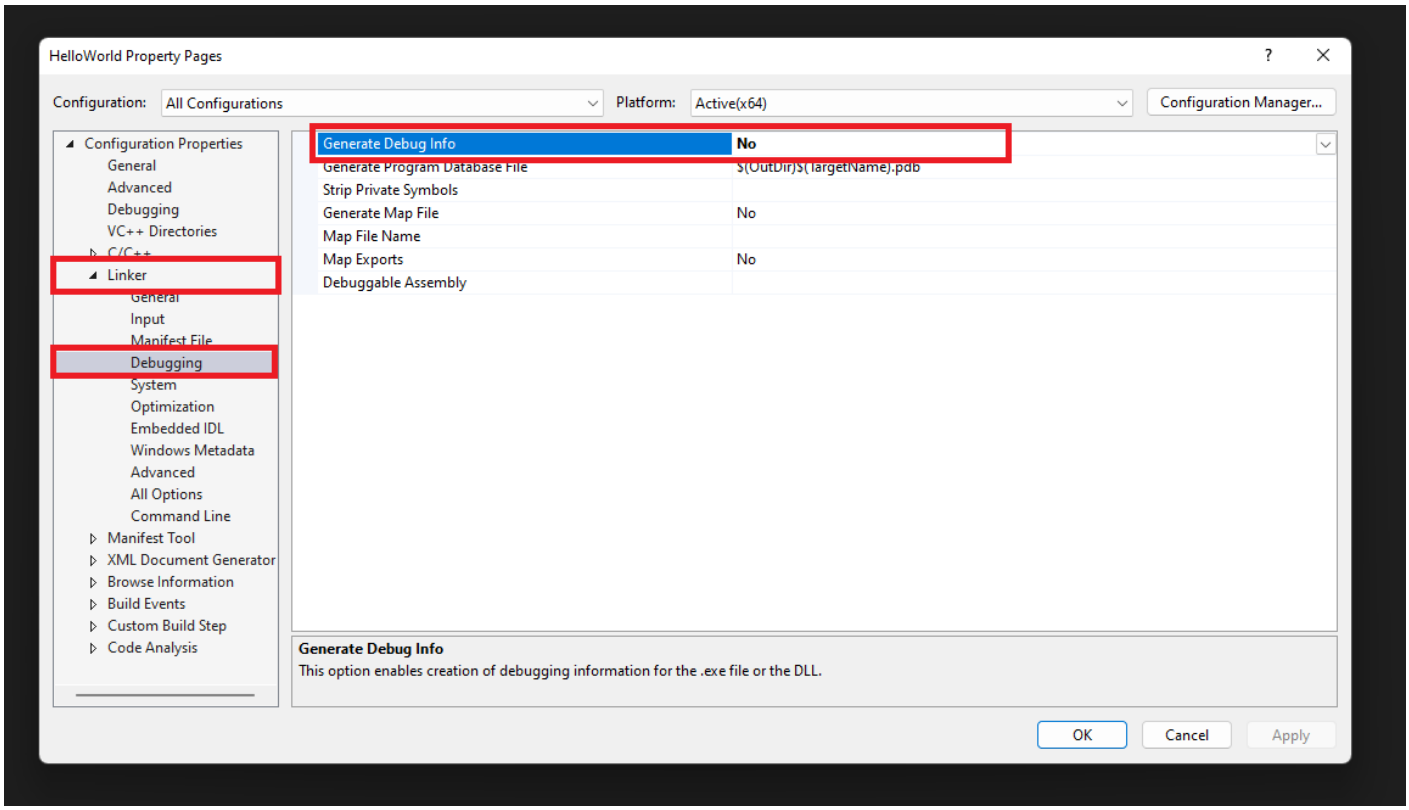
Disable Whole Program Optimization

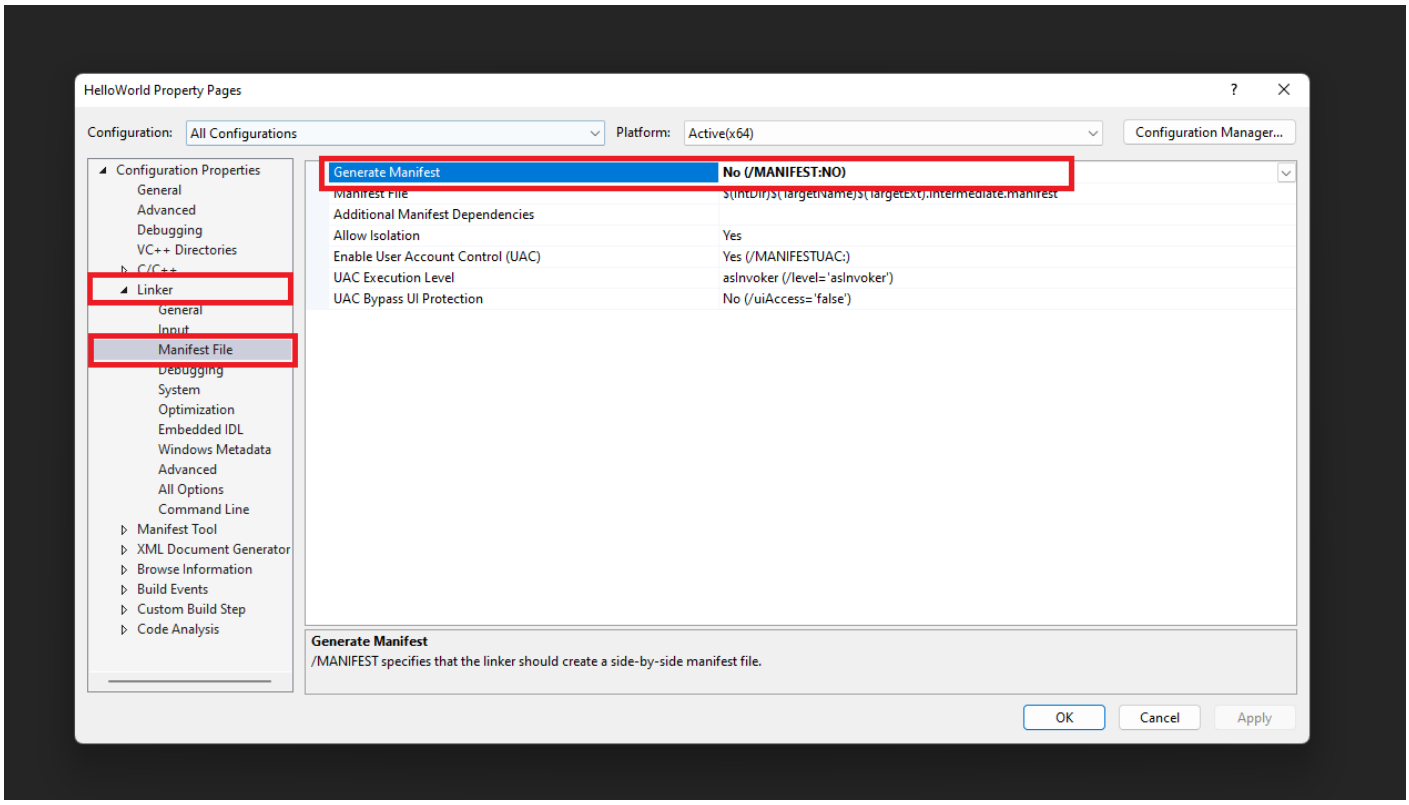
The *Whole Program Optimization* should be disabled to prevent the compiler from performing optimizations that may affect the stack. Disabling this option provides complete control over the compiled code.



Disable Debug Info

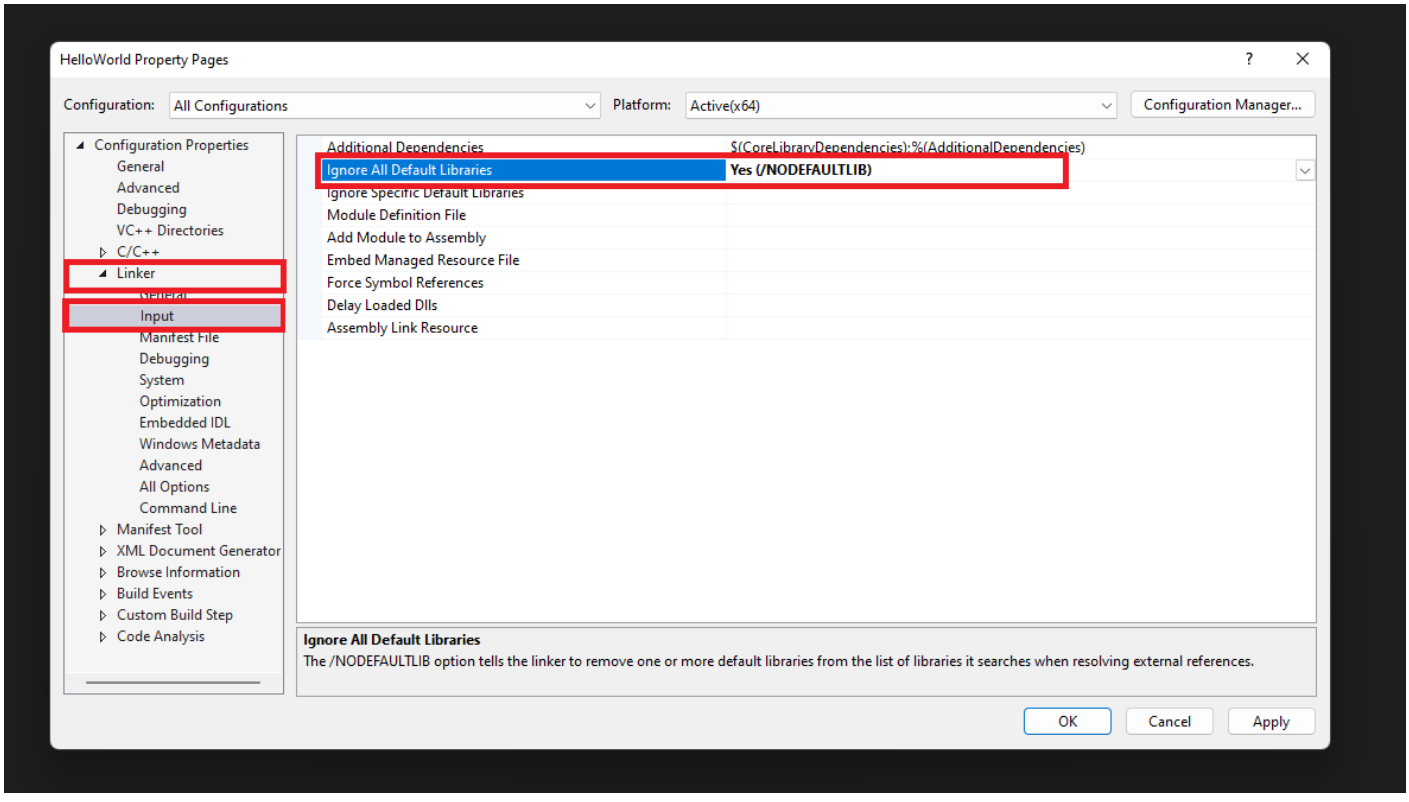
Disable the *Generate Debug Info* and *Generate Manifest* options to remove the added debugging information.



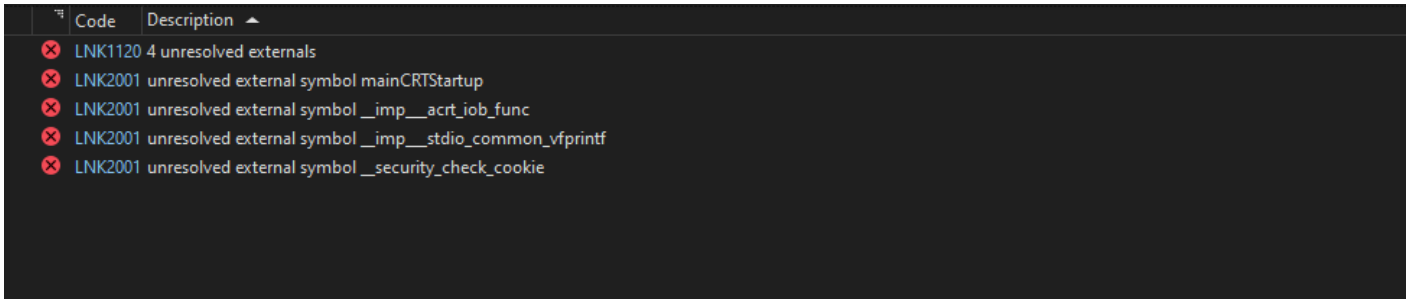


Ignore All Default Libraries

Set the *Ignore All Default Libraries* option to "Yes (/NODEFAULTLIB)" to exclude the default system libraries from being linked by the compiler with the program. This will result in the exclusion of the linking of the CRT Library as well as other libraries. In this case, it is the responsibility of the user to provide any required functions that are usually provided by these default libraries. The image below shows the "Yes (/NODEFAULTLIB)" option being set.

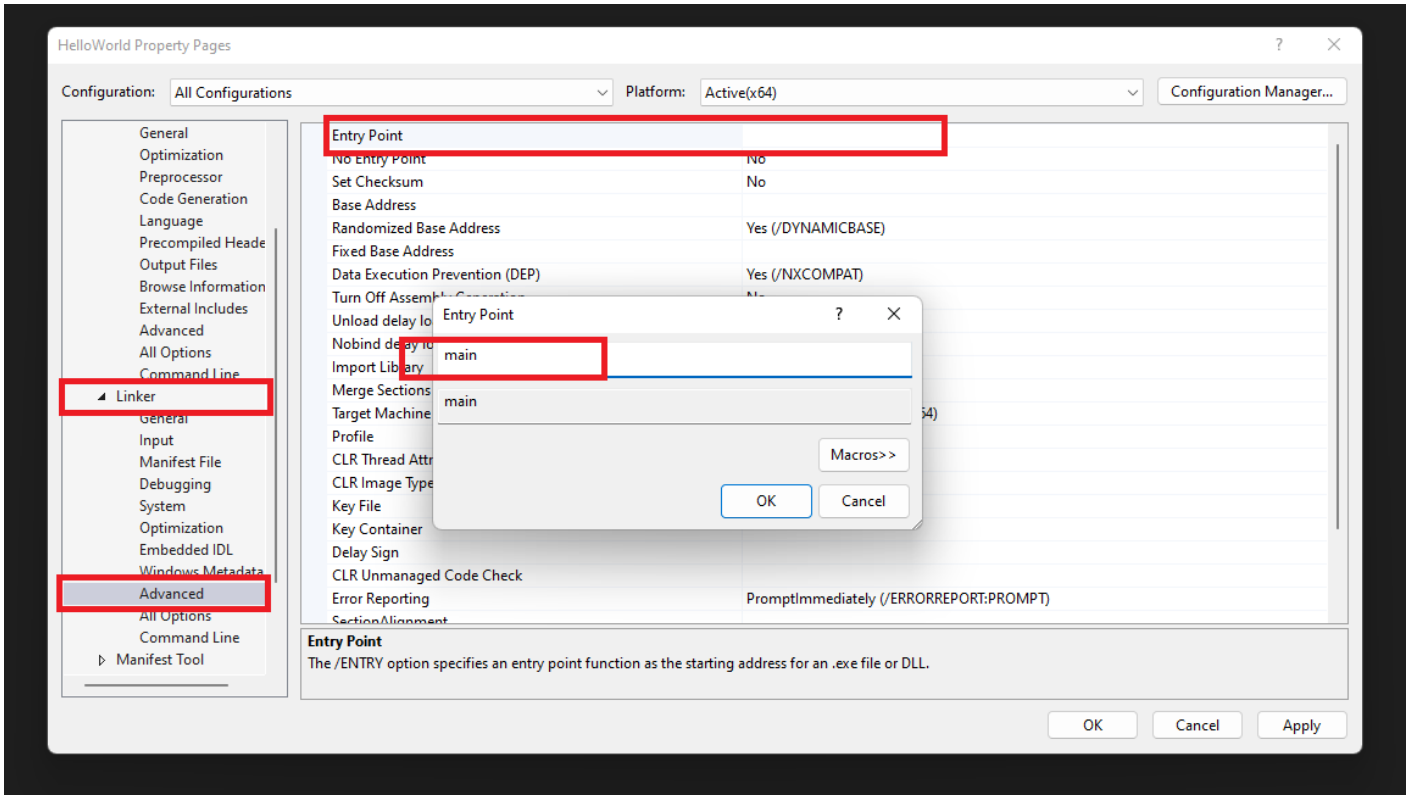


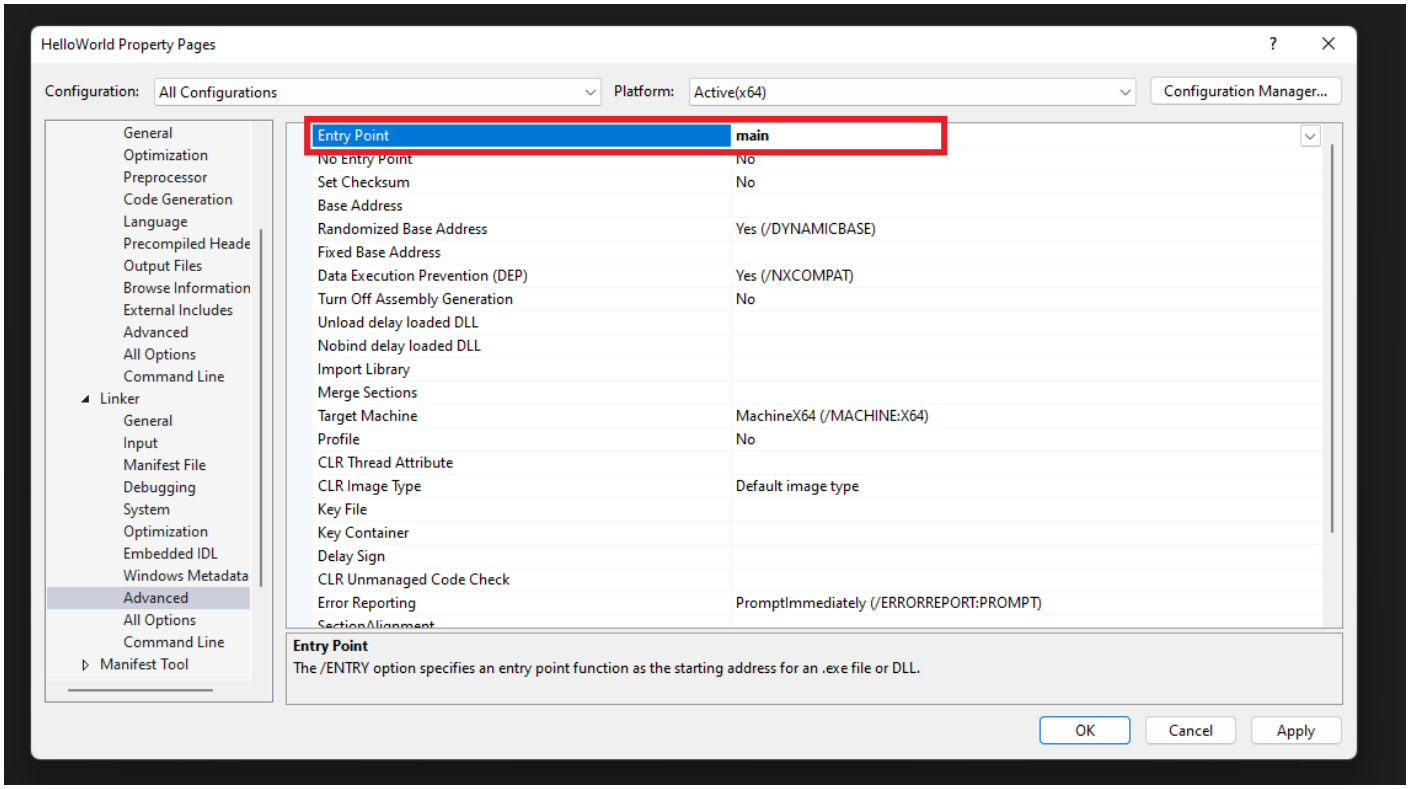
Unfortunately, compiling with that option results in several errors, as shown below.



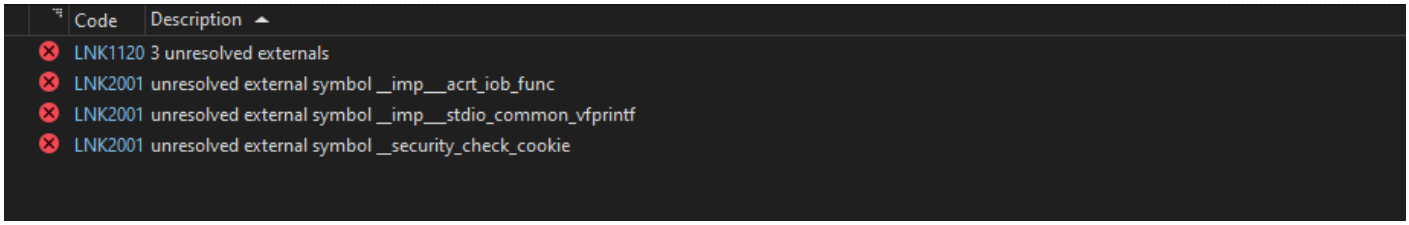
Setting Entry Point Symbol

The first error "LNK2001 - unresolved external symbol mainCRTStartup" implies that the compiler was unable to locate the definition for the "mainCRTStartup" symbol. This is expected as "mainCRTStartup" is the entry point for a program that has been linked with the CRT Library, which is not the case here. To resolve this issue, a new entry point symbol should be set as shown below.



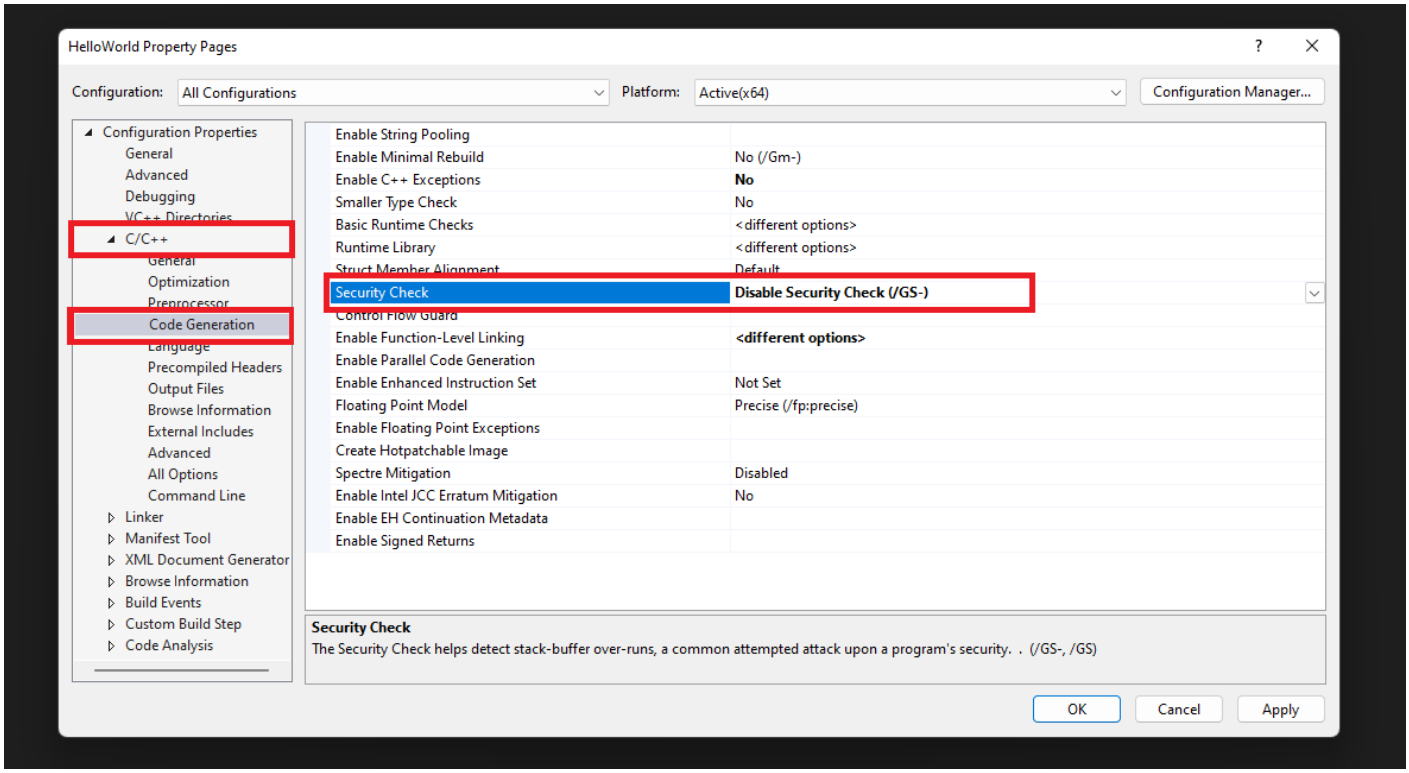


The entry "main" represents the main function in the source code. To choose a different function as an entry point, simply set the entry point symbol to that function's name. Recompiling results in fewer errors, as shown below.



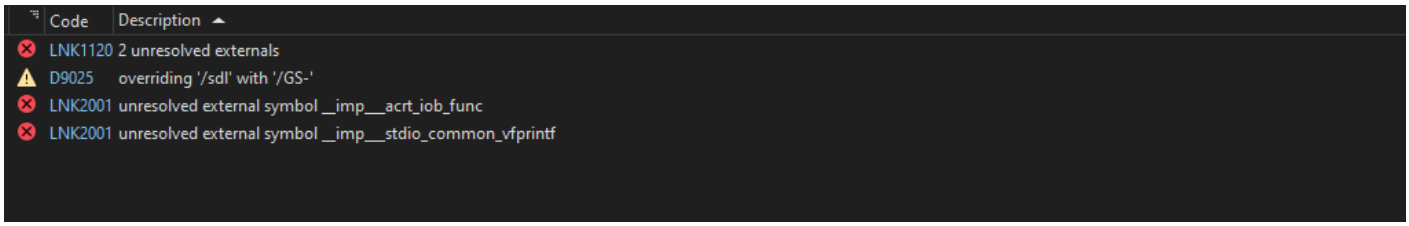
Disable Security Check

The next error, "LNK2001 - unresolved external symbol __security_check_cookie", means that the "__security_check_cookie" symbol was not found by the compiler. This is a symbol that is used to perform a stack cookie check which is a security feature that helps in preventing stack buffer overflows. To solve this, set the *Security Check* option to "Disable Security Check (/Gs-)" as shown below.

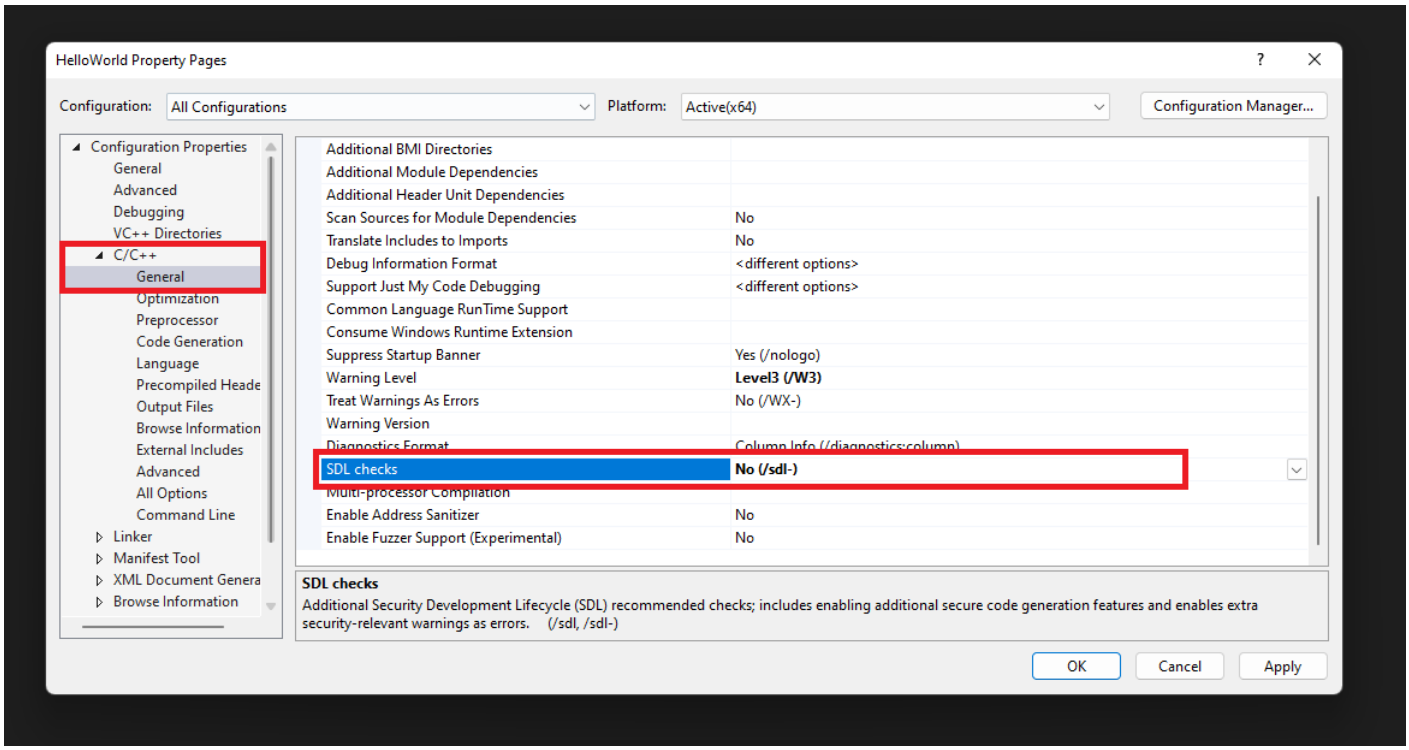


Disable SDL Checks

Once the security check is disabled, the error disappears but a new warning shows up.



The "D9025 - overriding '/sdl' with '/GS-'" warning can be resolved by disabling the Security Development Lifecycle (SDL) checks.



Two unresolved symbol errors remain, which are resolved in the *Functions Replacement* section below.

Replacing CRT Library Functions

Two errors remain unresolved due to the removal of the CRT Library. The `printf` function is currently being used to print to the console, although the CRT Library has been removed from the program.

When removing the CRT Library, writing one's own version of functions such as `printf`, `strlen`, `strcat`, `memcpy` is necessary. Libraries like VX-API may be used for this purpose. For example, StringCompare.cpp replaces the `strcmp` function for string comparison.

Replacing Printf

For the demo program used in this module, the `printf` function is replaced with the following macro.

```
#define PRINTA( STR, ... )
\
    if (1) {
\
        LPSTR buf = (LPSTR)HeapAlloc( GetProcessHeap(), HEAP_ZERO_MEMORY,
1024 );           \
        if ( buf != NULL ) {
\
```

```
            int len = wsprintfA( buf, STR, __VA_ARGS__ );
\
            WriteConsoleA( GetStdHandle( STD_OUTPUT_HANDLE ), buf, len,
NULL, NULL );       \
            HeapFree( GetProcessHeap(), 0, buf );
\
        }
\
    }
```

The `PRINTA` macro takes two arguments:

- `STR` - The format string which represents how to print the output.
- `__VA_ARGS__` or `...` - Which are the arguments to be printed.

The `PRINTA` macro allocates a heap buffer of size 1024 bytes, then uses the wsprintfA function to write formatted data from the variable arguments (`__VA_ARGS__`) into the buffer using the format string (`STR`). Subsequently, the WriteConsoleA WinAPI is used to write the resulting string to the console, which is obtained via the GetStdHandle WinAPI.

Replacing `printf` with `PRINTA` results in the `Hello World` program that is independent of the CRT Library. This code resolves any remaining errors and can now compile successfully.

```
#include <Windows.h>
#include <stdio.h>

#define PRINTA( STR, ... )
\
    if (1) {
\
        LPSTR buf = (LPSTR)HeapAlloc( GetProcessHeap(), HEAP_ZERO_MEMORY,
1024 );           \
        if ( buf != NULL ) {
\
            int len = wsprintfA( buf, STR, __VA_ARGS__ );
\
            WriteConsoleA( GetStdHandle( STD_OUTPUT_HANDLE ), buf, len,
NULL, NULL );       \
            HeapFree( GetProcessHeap(), 0, buf );
\
        }
\
    }
```

```
int main() {
   PRINTA("Hello World ! \n");
   return 0;

}
```

Building a CRT Library Independent Malware

When building malware that does not utilize the CRT Library, there are a few items to take note of.

Intrinsic Function Usage

Some functions and macros in Visual Studio use CRT functions to perform their tasks. For example, the `ZeroMemory` macro uses the CRT function `memset` to populate the specified buffer with zeros. This requires the developer to find an alternative to that macro since it cannot be used. In this case, the CopyMemoryEx.cpp function can be used as a replacement.

Another solution would be manually setting custom versions of CRT-based functions like `memset`. Forcing the compiler to deal with this custom function instead of using the CRT exported version. Sequentially, macros like `ZeroMemory` will also use this custom function.

To demonstrate this, a custom version of the `memset` function can be specified to the compiler in the following manner, using the `intrinsic` keyword.

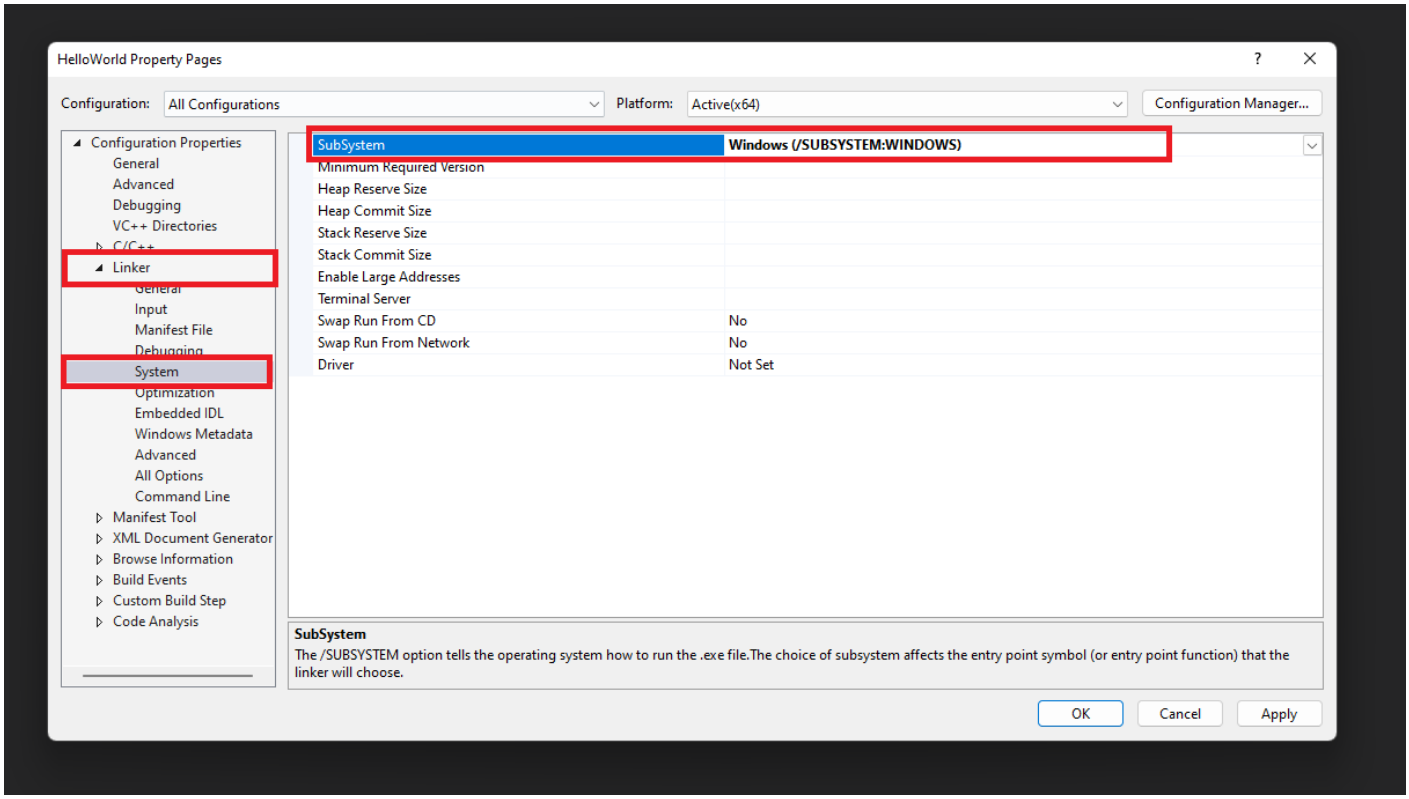
```
#include <Windows.h>

// The `extern` keyword sets the `memset` function as an external function.
extern void* __cdecl memset(void*, int, size_t);

// The `#pragma intrinsic(memset)` and #pragma function(memset) macros are
Microsoft-specific compiler instructions.
// They force the compiler to generate code for the memset function using a
built-in intrinsic function.
#pragma intrinsic(memset)
#pragma function(memset)

void* __cdecl memset(void* Destination, int Value, size_t Size) {
        // logic similar to memset's one
        unsigned char* p = (unsigned char*)Destination;
        while (Size > 0) {
                *p = (unsigned char)Value;
                p++;
                Size--;
        }
```

```
        return Destination;
}


int main() {

        PVOID pBuff = HeapAlloc(GetProcessHeap(), 0, 0x100);
        if (pBuff == NULL)
                return -1;

    // this will use our version of 'memset' instead of CRT's Library
version
        ZeroMemory(pBuff, 0x100);

        HeapFree(GetProcessHeap(), 0, pBuff);

        return 0;
}
```

Hiding The Console Window

Malware should not spawn a console window when executed, as this is highly suspicious and allows the user to terminate the program by closing the window. To prevent this, ShowWindow(NULL, SW_HIDE) can be used at the start of the entry point function, though this requires time (in milliseconds) and can cause a noticeable *flash*.

A better solution is to set the program to be compiled as a GUI program by setting the Visual Studio *SubSystem* option to "Windows (/SUBSYSTEM:WINDOWS)".



Demo

After performing all the steps explained in this module, the results are shown.

First, the binary size is reduced from 112.5kb to approximately 3kb.

```
PS C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release> ls


    Directory: C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release


Mode                 LastWriteTime         Length Name
----                 -------------         ------ ----
-a----          2/2/2023   7:07 AM           3072 HelloWorld.exe


PS C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release> .\HelloWorld.exe
Hello World !
PS C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release>
```

Next, no unused functions are found in the IAT.

```
PS C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release> dumpbin.exe /IMPORTS .\HelloWorld.exe
Microsoft (R) COFF/PE Dumper Version 14.32.31332.0
Copyright (C) Microsoft Corporation.  All rights reserved.


Dump of file .\HelloWorld.exe

File Type: EXECUTABLE IMAGE

  Section contains the following imports:

    KERNEL32.dll
             140002000 Import Address Table
             140002218 Import Name Table
                     0 time date stamp
                     0 Index of first forwarder reference

                         351 HeapAlloc
                         355 HeapFree
                         2BE GetProcessHeap
                         61A WriteConsoleA
                         2DC GetStdHandle

    USER32.dll
             140002030 Import Address Table
             140002248 Import Name Table
                     0 time date stamp
                     0 Index of first forwarder reference

                         3E9 wsprintfA

  Summary

        1000 .pdata
        1000 .rdata
        1000 .rsrc
        1000 .text
PS C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release>
```

Fewer strings are found in the binary with no debug information.

```
PS C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release> strings.exe .\HelloWorld.exe

Strings v2.54 - Search for ANSI and Unicode strings in binary images.
Copyright (C) 1999-2021 Mark Russinovich
Sysinternals - www.sysinternals.com

!This program cannot be run in DOS mode.
Rich1
.text
`.rdata
@.pdata
@WH
tVH
\$@H
D$
\$@3
Hello World !
GCTL
.text$mn
.idata$5
.rdata
.rdata$voltmd
.rdata$zzzdbg
.xdata
.idata$2
.idata$3
.idata$4
.idata$6
.pdata
GetStdHandle
HeapAlloc
HeapFree
GetProcessHeap
WriteConsoleA
KERNEL32.dll
wsprintfA
USER32.dll
PS C:\Users\User\Desktop\Intermediate\HelloWorld\x64\Release>
```

Finally, the removal of the CRT Library results in better evasion. The binary is uploaded to VirusTotal twice, the first time it is using the "Multi-threaded (/MT)" option to statically link the CRT library. The second time is when the CRT Library was completely removed.

?

Community Score

4 security vendors and no sandboxes flagged this file as malicious

9a37e1b7c966b55d7ae9a01112ace548e97e1e151b575d79b2c855c0c53ade6b

HelloWorld.exe

peexe 64bits assembly

122.00 KB
Size

?

Community Score

1 security vendor and no sandboxes flagged this file as malicious

aab55d37b08ef26932b478540822b53a1bad0cfaab03e3e3cbf160b08edb0d5a

HelloWorld.exe

peexe 64bits assembly

3.00 KB
Size