AN4226
Application note

Measuring STxP70 code size

Introduction

This document explains how to measure the code size of STxP70-4 applications. It describes two utilities (**stxp70-size** and **sxmeminfo**) delivered with the STxP70 toolset that measure the size of sections in the binary file.

In the early stages of firmware development, the size of C libraries is usually taken into account when measuring code size; however, in most embedded applications with tight memory constraints, the C libraries will not be part of the final memory footprint. *Chapter 4: Considering the size of libraries on page 9* describes a method of measuring the generated code size versus the library size, which can be used during the early stages of firmware development to get an idea of the real application code size.

Chapter 6: Considering the object file size on page 12 describes how measuring the code size on object files leads to a bias in the measurement. This is because the STxP70-4 architecture has a variable length instruction set with 16-, 32- and 48-bit instructions. During the compile stage, all possible instructions are provisioned as 48-bit instructions. During the link stage, the linker relaxes the code to the real 16-, 32- or 48- bit instructions. Moreover, dead code elimination is performed at the post-link stage using the binary optimizer. As a consequence, measuring the code size on the final executable file is the only way to get the real code size.

Finally, *Chapter 7* provides some tips to reduce the code size on STxP70.

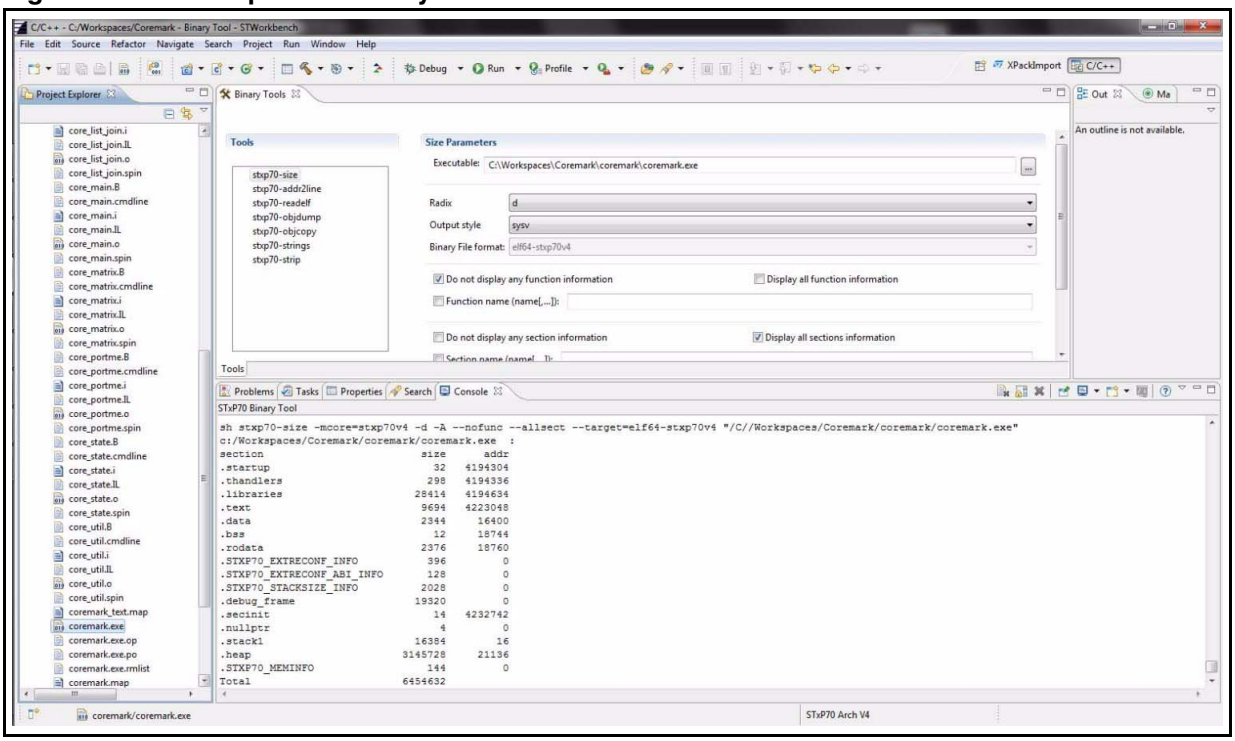
Contents

1 The stxp70-size utility

The STxP70 toolset provides a utility called **stxp70-size** that computes the size of each section in an ELF file.

The output of this utility depends on the application but the commonly used sections are described in this chapter.

Figure 1. The stxp70-size utility in STWorkbench



1.1 Code sections

The following sections are considered as code. In other words, the measurement of code size has to take these sections into account:

```
.startup      // Boot address code
.ivtable      // Interrupt vector table
.thandlers    // Hardware and software TRAP handlers
.ithandlers   // Interrupt handlers
.text         // Code section
```

1.2 Data sections

Data sections can be split in two types:

- read-only sections
- read-write sections

1.2.1 Read-only data sections

```
.rodata       // Read only data
.tda_ro       // Read only data in tiny data area (deprecated section)
.sda_ro1      // 8-bit aligned read only data in small data area
.sda_ro2      // 16-bit aligned read only data in small data area
.sda_ro4      // 32-bit aligned read only data in small data area
.sda_ro8      // 64-bit aligned read only data in small data area
.da_ro1       // 8-bit aligned read only data in data area
.da_ro2       // 16-bit aligned read only data in data area
.da_ro4       // 32-bit aligned read only data in data area
.da_ro8       // 64-bit aligned read only data in data area
.secinit      // Memory regions initialization table
```

1.2.2 Read-write data sections

```
.data         // Static global data area
.bss          // Uninitialized global and static data area
.tda_data     // Static tiny data area (deprecated section)
.tda_bss      // Uninitialized global and static tiny data area (deprecated
              // section)
.sda_data1    // 8-bit aligned static tiny data area
.sda_data2    // 16-bit aligned static tiny data area
.sda_data4    // 32-bit aligned static tiny data area
.sda_data8    // 64-bit aligned static tiny data area
.sda_bss1     // 8-bit aligned uninitialized global and static small data
              // area
.sda_bss2     // 16-bit aligned uninitialized global and static small data
              // area
.sda_bss4     // 32-bit aligned uninitialized global and static small data
              // area
.sda_bss8     // 64-bit aligned uninitialized global and static small data
              // area
.da_data1     // 8-bit aligned static data area
.da_data2     // 16-bit aligned static data area
.da_data4     // 32-bit aligned static data area
.da_data8     // 64-bit aligned static data area
.da_bss1      // 8-bit aligned uninitialized global and static data area
.da_bss2      // 16-bit aligned uninitialized global and static data area
.da_bss4      // 32-bit aligned uninitialized global and static data area
.da_bss8      // 64-bit aligned uninitialized global and static data area

.stack1       // Stack used by first context
.heap         // Dynamic data area
.ctors        // Constructors data
.dtors        // Destructors data
```

Note: The `.heap` and `.stack` sections represent the memory size allocated for these sections in the link script file. They do not represent the amount of stack and heap actually used by the application.

1.3 Other sections

Other sections are referenced in the ELF file but will not be part of the memory footprint on the device. This means debugging information can be kept for a program image residing in program memory without this information appearing in the program memory itself.

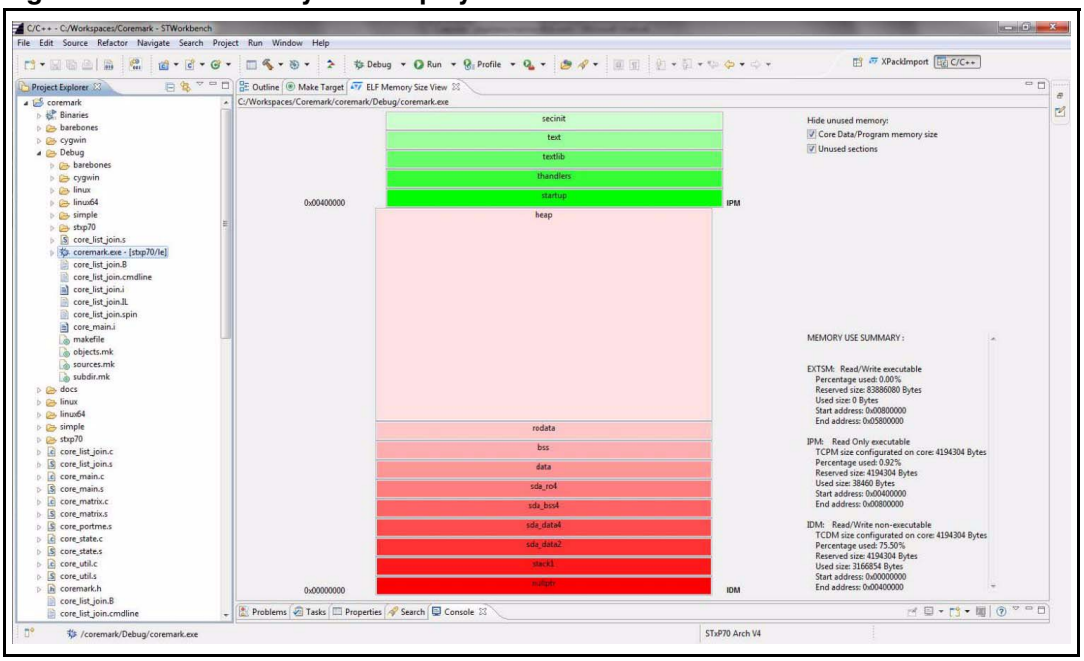
```
.debug_srcinfo
.debug_sfnames
.debug_aranges
.debug_pubnames
.debug_info
.debug_abbrev
.debug_line
.debug_frame
.debug_str
.debug_loc
.debug_macinfo
.debug_weaknames
.debug_funcnames
.debug_typenames
.debug_varnames

.STXP70_EXTRECONF_INFO
.STXP70_EXTRECONF_ABI_INFO
.STXP70_STACKSIZE_INFO
.STXP70_MEMINFO
```

2 The sxmeminfo utility

The functionality of the **sxmeminfo** utility is similar to the **stxp70-size** utility (see *Chapter 1*); however, it provides additional information such as the used code and data memory compared to the available memory sizes as defined in the link script file. It also provides a graphical interface.

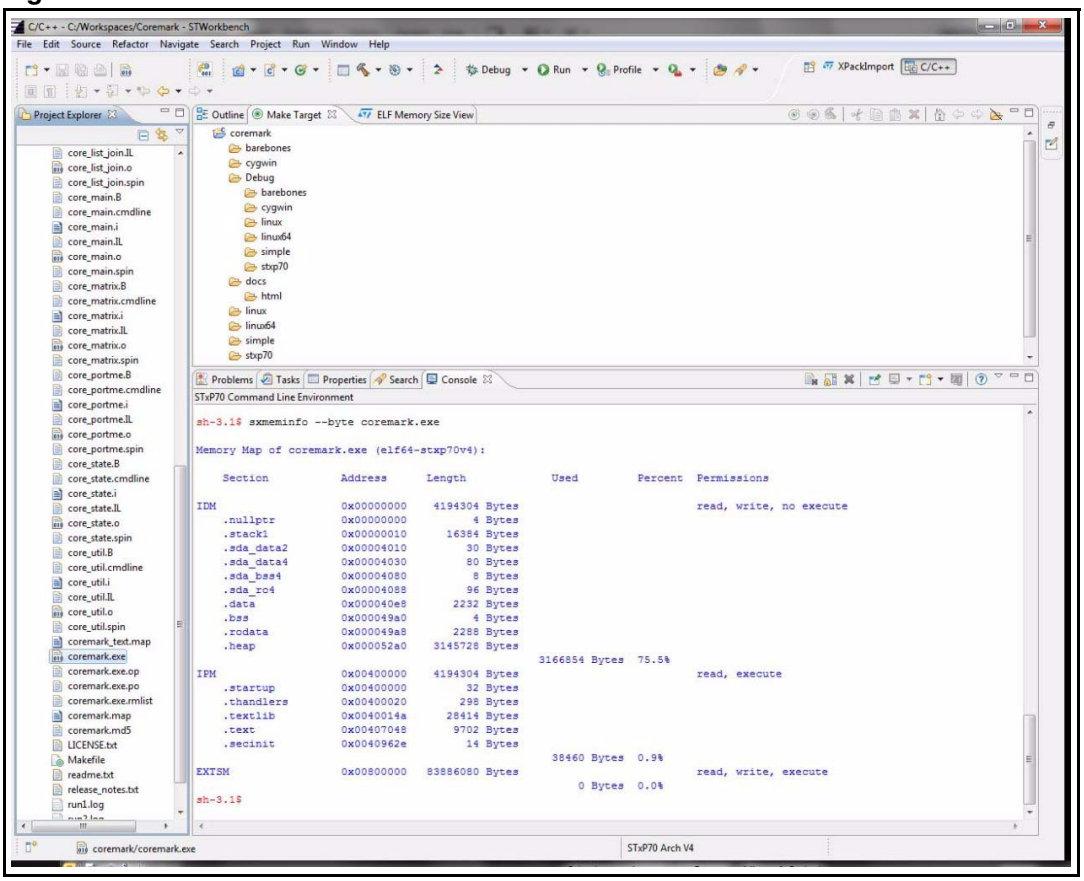
Figure 2. ELF memory size display in STWorkbench



To display a graph equivalent to the one in *Figure 2*, right click on the STxP70 executable (`coremark.exe` in this example) and select **ELF Memory Size Display**.

The **sxmeminfo** utility is also available on the command line as shown in *Figure 3*.

Figure 3. sxmeminfo command line in STWorkbench



3 Sizing the program and data memories

This chapter differentiates between two kinds of usage:

- non-volatile memory (the processor is stand-alone and boots from non-volatile memory)
- volatile memory (both the program and data memories are volatile and loaded at boot time by an external processor)

3.1 Non-volatile program memory

In this case, all the code sections as well as the read-only data sections have to be put in non-volatile program memory. In other words, all the sections described in *Section 1.1 on page 3* and *Section 1.2.1 on page 4* have to be put in non-volatile program memory.

All the remaining data sections (described in *Section 1.2.2 on page 4*) have to be placed in volatile data memory.

Note: If you are trying to minimize the memory footprint, you can leave the `.rodata` sections inside the non-volatile program memory during execution and avoid a copy in RAM. But for performance reasons, it may be wise to copy the `.rodata` sections described in Section 1.2.1 on page 4 (except the `.secinit` section) in data RAM as the processor is less efficient when accessing data from program memory.

3.2 Volatile program memory

If a host places the STxP70 code and data in its memory at start-up, all code sections have to be put in volatile program memory. In fact, only the tightly coupled program and external memories are executable by the STxP70 processor.

All data sections can be put in either volatile program memory or volatile data memory but code execution will always be more efficient if data is placed in tightly coupled data memory. An example of section placement is shown in *Figure 4*.

Figure 4. Section placement with volatile program memory

```
sh stxp70-readelf -mcore=stxp70v4 -l -W "/C//Workspaces/Coremark/coremark/coremark.exe"

Elf file type is EXEC (Executable file)
Entry point 0x400000
There are 4 program headers, starting at offset 64

Program Headers:
  Type           Offset   VirtAddr           PhysAddr           FileSiz  MemSiz   Flg Align
  LOAD           0x001000 0x0000000000000000 0x0000000000000000 0x000004 0x004010 RW  0x1000
  LOAD           0x001010 0x0000000000004010 0x0000000000004010 0x000990 0x000994 RW  0x1000
  LOAD           0x0019a8 0x00000000000049a8 0x00000000000049a8 0x0008f0 0x3008f8 RW  0x1000
  LOAD           0x003000 0x0000000000400000 0x0000000000400000 0x00963c 0x00963c RWE 0x1000

 Section to Segment mapping:
  Segment Sections...
   00     .nullptr .stack1
   01     .sda_data2 .sda_data4 .sda_bss4 .sda_ro4 .data .bss
   02     .rodata .heap
   03     .startup .thandlers .textlib .text .secinit
```

4 Considering the size of libraries

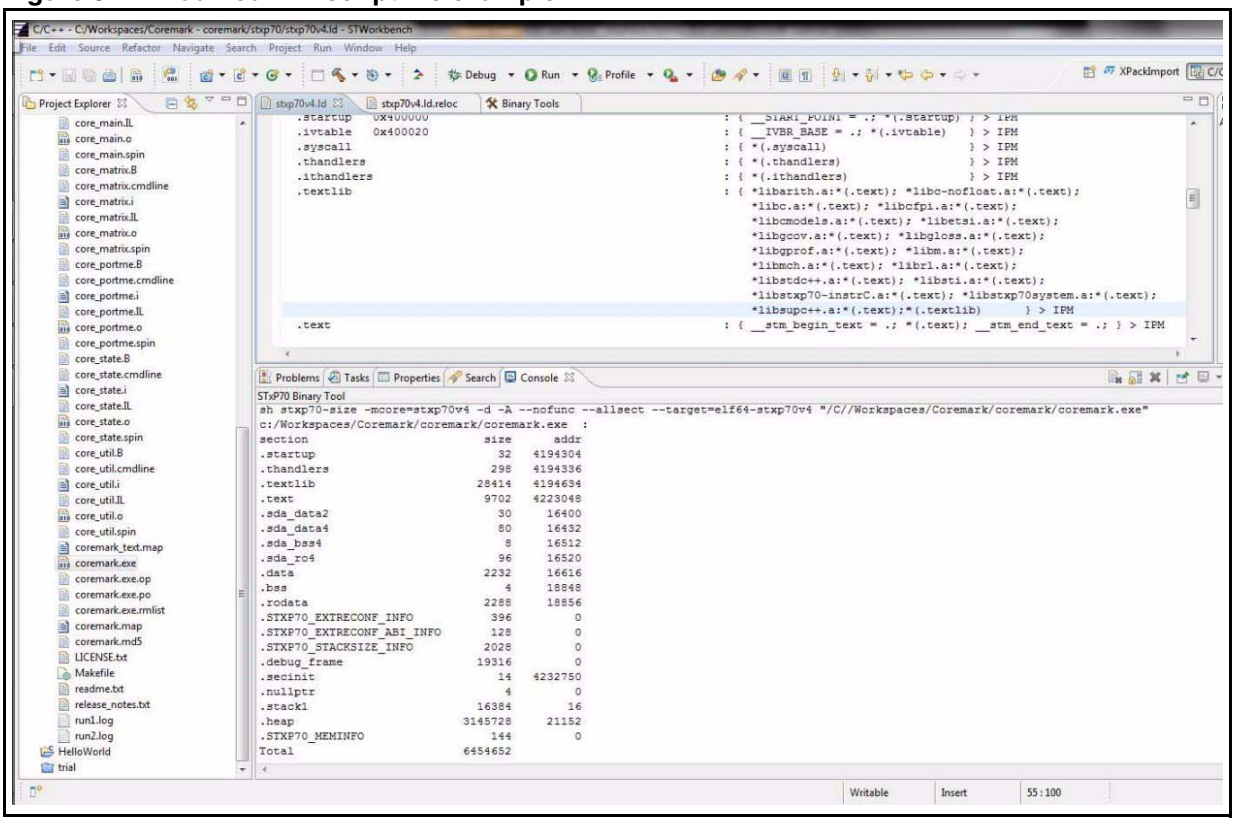
In the early stages of firmware development, the size of C libraries is usually taken into account when measuring code size; however, in most embedded applications with tight memory constraints, the C libraries will not be part of the final memory footprint (refer to *Chapter 7: Tips and tricks to reduce code size on page 15* for some hints on achieving this).

This chapter describes a method of measuring the generated code size versus the library size, which can be used during the early stages of firmware development to get an idea of the real application code size.

4.1 Link script file

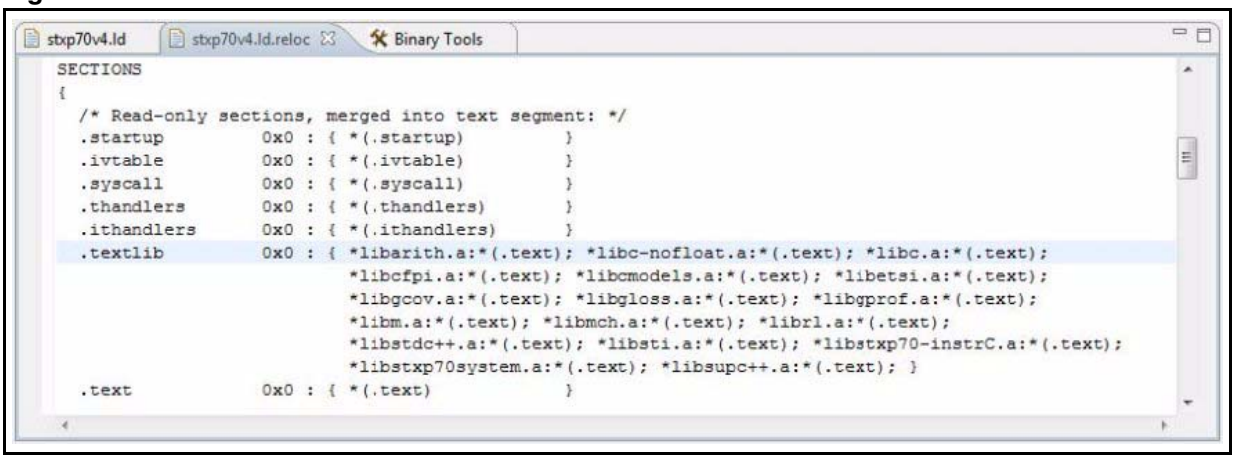
Redirect the libraries to a specific `.text` section called `.textlib` by modifying the link script file as shown in *Figure 5*.

Figure 5. Modified link script file example



The `stxp70v4.ld.reloc` file also has to be modified to redirect the libraries to this specific section at high optimization levels (Os, O2, O3 and O4), see *Figure 6*.

Figure 6. Relocatable file



The `.text` section is now split in two sections: the application code itself in the `.text` section and the C libraries in the `.textlib` section. These modifications to the `.ld` and `.ld.reloc` files are implemented by default in the STxP70 toolset R2012.2 and later versions.

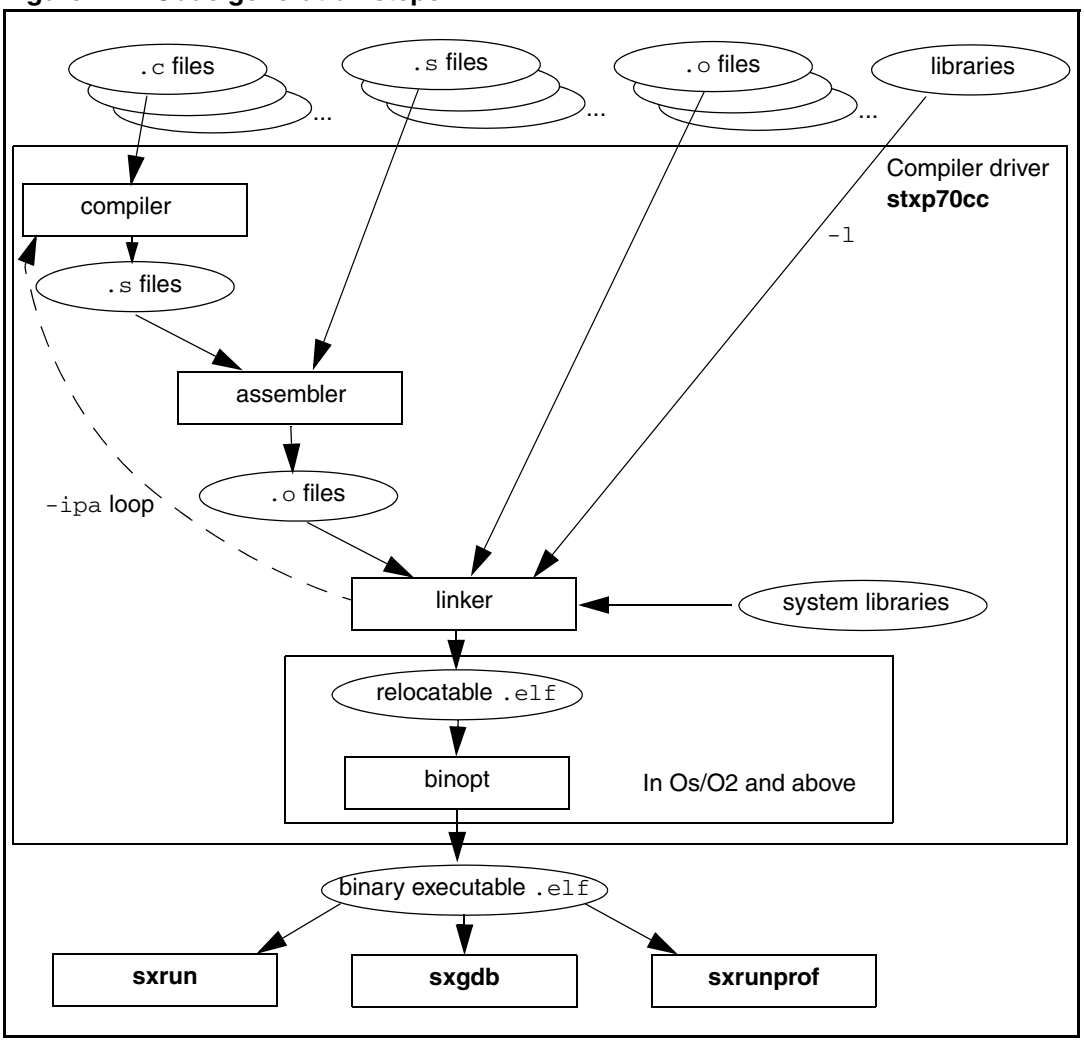
Note: As shown in Figure 5, the library size is much bigger than the application size itself. This is often the case for small applications so only reference library functions that are required.

5 Code generation steps (reminder)

This chapter provides a reminder of the steps taken during code generation. *Figure 7* illustrates the complete steps.

1. The `.c` source files are individually compiled into generated `.s` assembly files.
2. The generated assembly files and `.s` source files are individually assembled to generate `.o` object files.
3. All `.o` objects files are linked with the libraries to generate the final binary file in ELF format.

Figure 7. Code generation steps



6 Considering the object file size

Measuring the code size on object files leads to a bias in the measurement. The STxP70-4 architecture has a variable length instruction set with 16-, 32- and 48-bit instructions. During the compile stage, all possible instructions are provisioned as 48-bit instructions. During the link stage, the linker relaxes the code to the real 16-, 32- or 48- bit instructions. Moreover, dead code elimination is performed at the post-link stage using the binary optimizer. As a consequence, measuring the code size on the final executable file is the only way to get the real code size.

In the example in *Figure 8*, adding the code size of the different `.o` files (that is, the sum of the `.text` section sizes excluding libraries) will lead to 17526 bytes. But the real application size is 10318 bytes as shown in *Figure 9*. As a conclusion, we can say that measuring the code size on object files is not a valid measurement.

Figure 8. Measuring the code size on object files

```
$ stxp70v4-size *.o
core_list_join.o  :
section                      size   addr
.text                        4208      0
.data                           0      0
.bss                            0      0
.debug_frame                  816      0
.STXP70_EXTRECONF_INFO        396      0
.STXP70_EXTRECONF_ABI_INFO    128      0
.STXP70_STACKSIZE_INFO        144      0
Total                        11384

core_main.o  :
section                      size   addr
.text                        2762      0
.data                          44      0
.bss                            0      0
.rodata                      1240      0
.debug_frame                  300      0
.STXP70_EXTRECONF_INFO        396      0
.STXP70_EXTRECONF_ABI_INFO    128      0
.STXP70_STACKSIZE_INFO         24      0
Total                        9788

core_matrix.o  :
section                      size   addr
.text                        4888      0
.data                           0      0
.bss                            0      0
.debug_frame                  808      0
.STXP70_EXTRECONF_INFO        396      0
.STXP70_EXTRECONF_ABI_INFO    128      0
.STXP70_STACKSIZE_INFO        108      0
Total                        12656

core_portme.o  :
section                      size   addr
.text                         272      0
.data                           4      0
.bss                            8      0
.debug_frame                  244      0
.STXP70_EXTRECONF_INFO        396      0
.STXP70_EXTRECONF_ABI_INFO    128      0
.STXP70_STACKSIZE_INFO         96      0
Total                        2296

core_state.o  :
section                      size   addr
.text                        3672      0
.data                          64      0
.bss                            0      0
.rodata                       304      0
.debug_frame                  268      0
.STXP70_EXTRECONF_INFO        396      0
.STXP70_EXTRECONF_ABI_INFO    128      0
.STXP70_STACKSIZE_INFO         36      0
Total                        9736

core_util.o  :
section                      size   addr
.text                        1724      0
.data                           0      0
.bss                            0      0
.debug_frame                  228      0
.STXP70_EXTRECONF_INFO        396      0
.STXP70_EXTRECONF_ABI_INFO    128      0
.STXP70_STACKSIZE_INFO         84      0
Total                        5120
```

Figure 9. Measuring the code size on the final executable

```
$ stxp70v4-size coremark.exe
coremark.exe  :
section                          size      addr
.startup                           32   4194304
.thandlers                        298   4194336
.textlib                        28414   4194634
.text                           10318   4223048
.data                            2344     16400
.bss                               12     18744
.rodata                          2384     18760
.STXP70_EXTRECONF_INFO            396         0
.STXP70_EXTRECONF_ABI_INFO        128         0
.STXP70_STACKSIZE_INFO           2028         0
.debug_frame                    19508         0
.secinit                           14   4233366
.nullptr                            4         0
.stack1                         16384        16
.heap                         3145728     21152
.STXP70_MEMINFO                   144         0
Total                         6456272
```

Note: Observe again the relatively large size of the libraries (28414 bytes) compared with the generated code size (10318 bytes) and refer to Chapter 7 which includes tips on reducing the size of these libraries.

7 Tips and tricks to reduce code size

7.1 Optimize for size

The C compiler provides efficient optimization options `-Os` and `-O2`. Use them on all files and as linker options as well. Refer to the *STxP70 compiler user manual* (8027948) for more details on how to use these options.

7.2 Avoid using IPA

Interprocedural analysis (IPA) is mainly a speed oriented optimization that generally impacts code size. Avoid using the `-ipa` option if your goal is to compile for size.

7.3 Use the SDA section

On some applications, using the small data area (SDA) instead of the standard data area (DA) reduces code size. Data accessed in this section only uses one instruction instead of two. Depending on the size of each of those instructions, this may help reduce code size.

To place all variables in the SDA memory area, use the `-Msda=all` compiler option.

If the variables do not all fit in this memory area, place only the variables with a given alignment (`-Msda=1`, `-Msda=2`, `-Msda=4` or `-Msda=8`) in these memory areas.

Individual variables can also be placed in these memory areas using attributes (refer to the *STxP70 compiler user manual* (8027948) for details).

7.4 Write your own I/O functions

`printf`, `scanf` and some derivative library functions are very powerful but very large functions. They support different variable types that may not be required if the required output is a fixed string or a fixed number of values of known types.

Instead, `puts`/`putchar` can be used to deal with constant strings or characters. You may also write your own I/O functions if you know the number and type of the variables you need to display.

7.5 Use the floating point extension

If the application code contains floating point data, it is better to use the floating point extension (FPx). Otherwise, the C compiler embeds the necessary floating point emulation library functions that are usually code consuming.

The FPx is a single precision floating point extension and therefore the `-fshort-double` option should be added to avoid embedding the 64-bit floating point emulation library.

```
$ stxp70cc -mcore=stxp70v4 -Mextension=fpx -fshort-double -Os
-corecfg1=0xc00 -corecfg=0x7390149c MyFloatingPointApplication.c
```

8 Reference documentation

- *STxP70-4.4.0 core and instruction set architecture manual* (Doc ID 023738)
- *STxP70-4C processor supercore datasheet* (Doc ID 023687)
- *STxP70 toolset user manual* (8204323)
- *STxP70 compiler user manual* (8027948)
- *STxP70 utilities reference manual* (8210925)
- *STxP70 compiler guidelines* (available in the toolset documentation portal)

9 Revision history

Table 1. Document revision history

Date	Revision	Changes
30-Jan-2013	1	Initial release.