

Link 3A. Static Linking Overview

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1 Static Linking Overview

- Based on
- Creating Static Libraries
- Static Linking Examples
- `gcc -l, -L, and -Wl,option`

"Self-service Linux: Mastering the Art of Problem Determination",

Mark Wilding

"Computer Architecture: A Programmer's Perspective",

Bryant & O'Hallaron

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Compiling 32-bit program on 64-bit gcc

- `gcc -v`
- `gcc -m32 t.c`
- `sudo apt-get install gcc-multilib`
- `sudo apt-get install g++-multilib`
- `-m32`
- `gcc-multilib`
- `g++-multilib`

Example 1 codes

main.c

```
#include <stdio.h>
#include "calc_mean.h"

int main(int argc, char* argv[]) {

    double m, v1 =5.2, v2 =7.9;

    m = mean(v1, v2);

    printf("The mean ");
    printf("of %3.2f ", v1);
    printf("and %3.2f ", v2);
    printf("is %3.2f\n", m);

    return 0;
}
```

calc_mean.h

```
double mean(double, double);
```

calc_mean.c

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

double mean(double a, double b) {
    return (a+b) / 2;
}
```

<http://lsi.vc.ehu.eus/pablogn/docencia/ISO/Act5%20Libs/crealibdin.html>

Example 1 creating a static library libmean.a

- a **static library** is basically a set of object files that were copied into a single file
 - first, `calc_mean.c` is turned into an object file:
`gcc -c calc_mean.c -o calc_mean.o`
 - then, the archiver (**ar**) is invoked to produce a **static library** (named `libmean.a`) out of the object file `calc_mean.o`
`ar rcs libmean.a calc_mean.o`
 - a library name must start with **lib** and have the suffix **.a**.

<http://lsi.vc.ehu.eus/pablogn/docencia/ISO/Act5%20Libs/crealibdin.html>

Example | the archiver ar

- **ar** : a Linux tool to create, modify, and extract from archives
some options
 - **r** replace files existing inside the archive
 - **c** create an archive if not already present
 - **s** create an object-file index into the archive

<https://stackoverflow.com/questions/2734719/how-to-compile-a-static-library-in-linux>

Example 1 creating a shared library libmean.so (1)

- when an object file is created for shared libraries, it must be position independent

- use the `-fPIC` option for a position independent code

```
gcc -c -fPIC calc_mean.c -o calc_mean.o
```

- create a shared library with the `-shared` option

```
gcc -shared -o libmean.so calc_mean.o
```

to follow linux naming convention

```
gcc -shared -Wl,-soname,libmean.so.1 -o libmean.so.1.0.1 calc_mean.o
```

- a library name must start with `lib` and have the suffix `.so`.

<http://lsi.vc.ehu.es/pablogn/docencia/ISO/Act5%20Libs/crealibdin.html>

Example 1 (3-2)

- For some reason, gcc says:
`cc1: warning: -fPIC ignored for target (all code is position independent)`
- It looks like `-fPIC` is not necessary on x86, but all manuals say, it's needed, so I use it too.
- Note: the library must start with the three letter `lib`

<http://lsi.vc.ehu.eus/pablogn/docencia/ISO/Act5%20Libs/crealibdin.html>

Example 1 (5-1)

- Linking against static library (`libmean.a`)

```
gcc -static main.c -o s_linked -L. -lmean
```

- the first three letters (the `lib`) must not be specified,
- as well as the suffix (`.a`)

- Executing the statically linked program

```
./s_linked
```

<http://lsi.vc.ehu.eus/pablogn/docencia/ISO/Act5%20Libs/crealibdin.html>

Example 1 (5-2)

- Linking against shared library (`libmean.so`)

```
gcc main.c -o d_linked -L. -lmean
```

- e first three letters (the lib) must not be specified,
- as well as the suffix (`.so`)

- Executing the dynamically linked program

```
LD_LIBRARY_PATH=.  
./d_linked
```

<http://lsi.vc.ehu.eus/pablogn/docencia/ISO/Act5%20Libs/crealibdin.html>

Example II (1)

- `gcc -c -o out.o out.c`
- `-c` means to create an intermediary object file, rather than an executable.
- `ar rcs libout.a out.o`
- This creates the static library. `r` means to insert with replacement, `c` means to create a new archive, and `s` means to write an index. As always, see the man page for more info.

<https://stackoverflow.com/questions/2734719/how-to-compile-a-static-library-in-linux>

Example II (2)

```
TARGET = prog
$(TARGET): main.o lib.a gcc $^ -o $@
main.o: main.c gcc -c $< -o $@
lib.a: lib1.o lib2.o ar rcs $@ $^
lib1.o: lib1.c lib1.h gcc -c -o $@ $<
lib2.o: lib2.c lib2.h gcc -c -o $@ $<
clean: rm -f *.o *.a $(TARGET)
```

<https://stackoverflow.com/questions/2734719/how-to-compile-a-static-library-in-linux>

Example II (3)

explaining the makefile:

target: prerequisites - the rule head $\$@$ - means the target $\$^$ - means all prerequisites $\$<$ - means just the first prerequisite

<https://stackoverflow.com/questions/2734719/how-to-compile-a-static-library-in-linux>

Example II (5)

main.c

```
#include <stdio.h>

#include "lib.h"

int main ( void )
{
    fun1(10);
    fun2(10);
    return 0;
}
```

lib.h

```
#ifndef LIB_H_INCLUDED
#define LIB_H_INCLUDED

#include "lib1.h"
#include "lib2.h"

#endif
```

<https://stackoverflow.com/questions/2734719/how-to-compile-a-static-library-in-linux>

Example II (6)

lib1.c

```
#include "lib1.h"

#include <stdio.h>

void fun1 ( int x )
{
    printf("%i\n",x);
}
```

lib1.h

```
#ifndef LIB1_H_INCLUDED
#define LIB1_H_INCLUDED

#ifdef __cplusplus
    extern "C" {
#endif

void fun1 ( int x );

#ifdef __cplusplus
    }
#endif

#endif /* LIB1_H_INCLUDED */
```

<https://stackoverflow.com/questions/2734719/how-to-compile-a-static-library-in-linux>

Example II (7)

lib2.c

```
#include "lib2.h"

#include <stdio.h>

void fun2 ( int x )
{
    printf("%i\n",2*x);
}
```

lib2.h

```
#ifndef LIB2_H_INCLUDED
#define LIB2_H_INCLUDED

#ifdef __cplusplus
    extern "C" {
#endif

void fun2 ( int x );

#ifdef __cplusplus
    }
#endif

#endif /* LIB2_H_INCLUDED */
```

<https://stackoverflow.com/questions/2734719/how-to-compile-a-static-library-in-linux>

Static Linking Examples

- 1 Example Program
- 2 Static Linking Procedures
- 3 Static Linking Commands

Example Program

main.c

```
void swap();

int buf[2] = {1, 2};

int main()
{
    int tmp;

    swap();

    return 0;
}
```

swap.c

```
extern int buf[];

int *p0 = &buf[0];
int *p1;

void swap()
{
    int tmp;

    p1 = &buf[1];

    tmp = *p0;
    *p0 = *p1;
    *p1 = tmp;
}
```

Static Linking Procedures

| | | | |
|-----|--------------|--------|--------|
| cpp | preprocessor | main.c | main.i |
| cc1 | compiler | main.i | main.s |
| as | assemble | main.s | main.o |
| cpp | preprocessor | swap.c | swap.i |
| cc1 | compiler | swap.i | swap.s |
| as | assemble | swap.s | swap.o |
| ld | linker | main.o | p |
| | | swap.o | |

Static Linking Commands

```
cpp main.c main.i
cc1 main.i -O2 -m32 -o main.s
as --32 -o main.o main.s
```

```
cpp swap.c swap.i
cc1 swap.i -O2 -m32 -o swap.s
as --32 -o swap.o swap.s
```

```
gcc -o p main.o swap.o
```

```
alias cc1=/usr/lib/gcc/x86_64-linux-gnu/5/cc1
```

```
ld -m elf_i386 -o p main.o swap.o -lc --entry_main --> not working
```

```
readelf -a main.o
readelf -a swap.o
```

Intermediate and Assembly Files (main.i, main.s)

- 1 main.i
- 2 main.s

```
# 1 "main.c"
# 1 "<built-in>"
# 1 "<command-line>"
# 1 "/usr/include/stdc-predef.h" 1 3 4
# 1 "<command-line>" 2
# 1 "main.c"
void swap();

int buf[2] = {1, 2};

int main()
{
    int tmp;

    swap();

    return 0;
}
```

main.s (1)

```
.file      "main.i"
.section   .text.unlikely,"ax",@progbits
.LCOLDB0:
.section   .text.startup,"ax",@progbits
.LHOTB0:
.p2align  4,,15
.globl    main
.type     main, @function

main:
.LFB0:
.cfi_startproc
leal     4(%esp), %ecx
.cfi_def_cfa 1, 0
andl    $-16, %esp
pushl   -4(%ecx)
pushl   %ebp
.cfi_escape 0x10,0x5,0x2,0x75,0
movl    %esp, %ebp
pushl   %ecx
.cfi_escape 0xf,0x3,0x75,0x7c,0x6
```


main.s (2)

```
    subl     $4, %esp
    call    swap
    addl     $4, %esp
    xorl     %eax, %eax
    popl     %ecx
    .cfi_restore 1
    .cfi_def_cfa 1, 0
    popl     %ebp
    .cfi_restore 5
    leal    -4(%ecx), %esp
    .cfi_def_cfa 4, 4
    ret
    .cfi_endproc

.LFE0:
    .size    main, .-main
    .section .text.unlikely

.LCOLDE0:
    .section .text.startup
```

```
.LHOTE0:  
    .globl      buf  
    .data  
    .align 4  
    .type      buf, @object  
    .size      buf, 8  
  
buf:  
    .long      1  
    .long      2  
    .ident     "GCC: (Ubuntu 5.4.0-6ubuntu1~16.04.4) 5.4.0 20160609"  
    .section   .note.GNU-stack,"",@progbits
```

Intermediate and Assembly Files (swap.i, swap.s)

- 1 swap.i
- 2 swap.s

```
# 1 "swap.c"
# 1 "<built-in>"
# 1 "<command-line>"
# 1 "/usr/include/stdc-predef.h" 1 3 4
# 1 "<command-line>" 2
# 1 "swap.c"
extern int buf[];

int *p0 = &buf[0];
int *p1;

void swap()
{
    int tmp;

    p1 = &buf[1];

    tmp = *p0;
    *p0 = *p1;
    *p1 = tmp;
}
```

swap.s (1)

```
.file "swap.i"
.section .text.unlikely,"ax",@progbits
.LCOLDB0:
.text
.LHOTB0:
.p2align 4,,15
.globl swap
.type swap, @function

swap:
.LFB0:
.cfi_startproc
movl    p0, %eax
movl    buf+4, %ecx
movl    $buf+4, p1
movl    (%eax), %edx
movl    %ecx, (%eax)
movl    %edx, buf+4
ret
.cfi_endproc
.LFE0:
.size   swap, .-swap
.section .text.unlikely
```

```
.LCOLDE0:  
    .text  
.LHOTE0:  
    .comm    p1,4,4  
    .globl  p0  
    .data  
    .align  4  
    .type   p0, @object  
    .size   p0, 4  
  
p0:  
    .long   buf  
    .ident  "GCC: (Ubuntu 5.4.0-6ubuntu1~16.04.4) 5.4.0 20160609"  
    .section      .note.GNU-stack,"",@progbits
```

Relocatable Object Files (main.o)

- 1 main.o ELF Header
- 2 main.o Section Header
- 3 main.o Section
- 4 main.o Symbol Table

main.o (1) ELF Header

ELF Header:

```
Magic: 7f 45 4c 46 01 01 01 00 00 00 00 00 00 00 00 00
Class: ELF32
Data: 2's complement, little endian
Version: 1 (current)
OS/ABI: UNIX - System V
ABI Version: 0
Type: REL (Relocatable file)
Machine: Intel 80386
Version: 0x1
Entry point address: 0x0
Start of program headers: 0 (bytes into file)
Start of section headers: 584 (bytes into file)
Flags: 0x0
Size of this header: 52 (bytes)
Size of program headers: 0 (bytes)
Number of program headers: 0
Size of section headers: 40 (bytes)
Number of section headers: 14
Section header string table index: 11
```


main.o (2) Section Header

Section Headers:

| [Nr] | Name | Type | Addr | Off | Size | ES | Flg | Lk | Inf | Al |
|------|-------------------|----------|----------|--------|--------|----|-----|----|-----|----|
| [0] | | NULL | 00000000 | 000000 | 000000 | 00 | | 0 | 0 | 0 |
| [1] | .text | PROGBITS | 00000000 | 000034 | 000000 | 00 | AX | 0 | 0 | 1 |
| [2] | .data | PROGBITS | 00000000 | 000034 | 000008 | 00 | WA | 0 | 0 | 4 |
| [3] | .bss | NOBITS | 00000000 | 00003c | 000000 | 00 | WA | 0 | 0 | 1 |
| [4] | .text.unlikely | PROGBITS | 00000000 | 00003c | 000000 | 00 | AX | 0 | 0 | 1 |
| [5] | .text.startup | PROGBITS | 00000000 | 000040 | 000021 | 00 | AX | 0 | 0 | 16 |
| [6] | .rel.text.startup | REL | 00000000 | 0001c4 | 000008 | 08 | I | 12 | 5 | 4 |
| [7] | .comment | PROGBITS | 00000000 | 000061 | 000035 | 01 | MS | 0 | 0 | 1 |
| [8] | .note.GNU-stack | PROGBITS | 00000000 | 000096 | 000000 | 00 | | 0 | 0 | 1 |
| [9] | .eh_frame | PROGBITS | 00000000 | 000098 | 000044 | 00 | A | 0 | 0 | 4 |
| [10] | .rel.eh_frame | REL | 00000000 | 0001cc | 000008 | 08 | I | 12 | 9 | 4 |
| [11] | .shstrtab | STRTAB | 00000000 | 0001d4 | 000074 | 00 | | 0 | 0 | 1 |
| [12] | .symtab | SYMTAB | 00000000 | 0000dc | 0000d0 | 10 | | 13 | 10 | 4 |
| [13] | .strtab | STRTAB | 00000000 | 0001ac | 000016 | 00 | | 0 | 0 | 1 |

Key to Flags:

W (write), A (alloc), X (execute), M (merge), S (strings)

I (info), L (link order), G (group), T (TLS), E (exclude), x (unknown)

0 (extra OS processing required) o (OS specific), p (processor specific)

main.o (3) Sections

There are no section groups in this file.

There are no program headers in this file.

Relocation section '.rel.text.startup' at offset 0x1c4 contains 1 entries:

| Offset | Info | Type | Sym.Value | Sym. Name |
|----------|----------|------------|-----------|-----------|
| 00000012 | 00000b02 | R_386_PC32 | 00000000 | swap |

Relocation section '.rel.eh_frame' at offset 0x1cc contains 1 entries:

| Offset | Info | Type | Sym.Value | Sym. Name |
|----------|----------|------------|-----------|---------------|
| 00000020 | 00000602 | R_386_PC32 | 00000000 | .text.startup |

The decoding of unwind sections for machine type Intel 80386 is not currently supported.

main.o (4) Symbol Table

Symbol table '.symtab' contains 13 entries:

| Num: | Value | Size | Type | Bind | Vis | Ndx | Name |
|------|----------|------|---------|--------|---------|-----|--------|
| 0: | 00000000 | 0 | NOTYPE | LOCAL | DEFAULT | UND | |
| 1: | 00000000 | 0 | FILE | LOCAL | DEFAULT | ABS | main.i |
| 2: | 00000000 | 0 | SECTION | LOCAL | DEFAULT | 1 | |
| 3: | 00000000 | 0 | SECTION | LOCAL | DEFAULT | 2 | |
| 4: | 00000000 | 0 | SECTION | LOCAL | DEFAULT | 3 | |
| 5: | 00000000 | 0 | SECTION | LOCAL | DEFAULT | 4 | |
| 6: | 00000000 | 0 | SECTION | LOCAL | DEFAULT | 5 | |
| 7: | 00000000 | 0 | SECTION | LOCAL | DEFAULT | 8 | |
| 8: | 00000000 | 0 | SECTION | LOCAL | DEFAULT | 9 | |
| 9: | 00000000 | 0 | SECTION | LOCAL | DEFAULT | 7 | |
| 10: | 00000000 | 33 | FUNC | GLOBAL | DEFAULT | 5 | main |
| 11: | 00000000 | 0 | NOTYPE | GLOBAL | DEFAULT | UND | swap |
| 12: | 00000000 | 8 | OBJECT | GLOBAL | DEFAULT | 2 | buf |

No version information found in this file.

Relocatable Object Files (swap.o)

- 1 swap.o ELF Header
- 2 swap.o Section Header
- 3 swap.o Section
- 4 swap.o Symbol Table

swap.o (1) ELF Header

ELF Header:

```
Magic: 7f 45 4c 46 01 01 01 00 00 00 00 00 00 00 00 00
Class: ELF32
Data: 2's complement, little endian
Version: 1 (current)
OS/ABI: UNIX - System V
ABI Version: 0
Type: REL (Relocatable file)
Machine: Intel 80386
Version: 0x1
Entry point address: 0x0
Start of program headers: 0 (bytes into file)
Start of section headers: 596 (bytes into file)
Flags: 0x0
Size of this header: 52 (bytes)
Size of program headers: 0 (bytes)
Number of program headers: 0
Size of section headers: 40 (bytes)
Number of section headers: 14
Section header string table index: 11
```

swap.o (2) Section Header

Section Headers:

| [Nr] | Name | Type | Addr | Off | Size | ES | Flg | Lk | Inf | Al |
|------|-----------------|----------|----------|--------|--------|----|------|----|-----|----|
| [0] | | NULL | 00000000 | 000000 | 000000 | 00 | | 0 | 0 | 0 |
| [1] | .text | PROGBITS | 00000000 | 000040 | 000020 | 00 | AX | 0 | 0 | 16 |
| [2] | .rel.text | REL | 00000000 | 0001b0 | 000028 | 08 | I 12 | | 1 | 4 |
| [3] | .data | PROGBITS | 00000000 | 000060 | 000004 | 00 | WA | 0 | 0 | 4 |
| [4] | .rel.data | REL | 00000000 | 0001d8 | 000008 | 08 | I 12 | | 3 | 4 |
| [5] | .bss | NOBITS | 00000000 | 000064 | 000000 | 00 | WA | 0 | 0 | 1 |
| [6] | .text.unlikely | PROGBITS | 00000000 | 000064 | 000000 | 00 | AX | 0 | 0 | 1 |
| [7] | .comment | PROGBITS | 00000000 | 000064 | 000035 | 01 | MS | 0 | 0 | 1 |
| [8] | .note.GNU-stack | PROGBITS | 00000000 | 000099 | 000000 | 00 | | 0 | 0 | 1 |
| [9] | .eh_frame | PROGBITS | 00000000 | 00009c | 00002c | 00 | A | 0 | 0 | 4 |
| [10] | .rel.eh_frame | REL | 00000000 | 0001e0 | 000008 | 08 | I 12 | | 9 | 4 |
| [11] | .shstrtab | STRTAB | 00000000 | 0001e8 | 00006a | 00 | | 0 | 0 | 1 |
| [12] | .symtab | SYMTAB | 00000000 | 0000c8 | 0000d0 | 10 | | 13 | 9 | 4 |
| [13] | .strtab | STRTAB | 00000000 | 000198 | 000017 | 00 | | 0 | 0 | 1 |

Key to Flags:

W (write), A (alloc), X (execute), M (merge), S (strings)

I (info), L (link order), G (group), T (TLS), E (exclude), x (unknown)

0 (extra OS processing required) o (OS specific), p (processor specific)

swap.o (3) Sections

There are no section groups in this file.

There are no program headers in this file.

Relocation section '.rel.text' at offset 0x1b0 contains 5 entries:

| Offset | Info | Type | Sym.Value | Sym. Name |
|----------|----------|----------|-----------|-----------|
| 00000001 | 00000a01 | R_386_32 | 00000000 | p0 |
| 00000007 | 00000b01 | R_386_32 | 00000000 | buf |
| 0000000d | 00000c01 | R_386_32 | 00000004 | p1 |
| 00000011 | 00000b01 | R_386_32 | 00000000 | buf |
| 0000001b | 00000b01 | R_386_32 | 00000000 | buf |

Relocation section '.rel.data' at offset 0x1d8 contains 1 entries:

| Offset | Info | Type | Sym.Value | Sym. Name |
|----------|----------|----------|-----------|-----------|
| 00000000 | 00000b01 | R_386_32 | 00000000 | buf |

Relocation section '.rel.eh_frame' at offset 0x1e0 contains 1 entries:

| Offset | Info | Type | Sym.Value | Sym. Name |
|----------|----------|------------|-----------|-----------|
| 00000020 | 00000202 | R_386_PC32 | 00000000 | .text |

The decoding of unwind sections for machine type Intel 80386 is not currently supported.

swap.o (4) Symbol Table

Symbol table '.symtab' contains 13 entries:

| Num: | Value | Size | Type | Bind | Vis | Ndx | Name |
|------|----------|------|---------|--------|---------|-----|--------|
| 0: | 00000000 | 0 | NOTYPE | LOCAL | DEFAULT | UND | |
| 1: | 00000000 | 0 | FILE | LOCAL | DEFAULT | ABS | swap.i |
| 2: | 00000000 | 0 | SECTION | LOCAL | DEFAULT | 1 | |
| 3: | 00000000 | 0 | SECTION | LOCAL | DEFAULT | 3 | |
| 4: | 00000000 | 0 | SECTION | LOCAL | DEFAULT | 5 | |
| 5: | 00000000 | 0 | SECTION | LOCAL | DEFAULT | 6 | |
| 6: | 00000000 | 0 | SECTION | LOCAL | DEFAULT | 8 | |
| 7: | 00000000 | 0 | SECTION | LOCAL | DEFAULT | 9 | |
| 8: | 00000000 | 0 | SECTION | LOCAL | DEFAULT | 7 | |
| 9: | 00000000 | 32 | FUNC | GLOBAL | DEFAULT | 1 | swap |
| 10: | 00000000 | 4 | OBJECT | GLOBAL | DEFAULT | 3 | p0 |
| 11: | 00000000 | 0 | NOTYPE | GLOBAL | DEFAULT | UND | buf |
| 12: | 00000004 | 4 | OBJECT | GLOBAL | DEFAULT | COM | p1 |

No version information found in this file.

Executable Object Files (p)

- 1 p ELF Header
- 2 p Section Header
- 3 p Program Header
- 4 p Section to Segment Mapping
- 5 p Dynamic Sections
- 6 p Misc Sections
- 7 p Symbol Table
- 8 p Others

p (1) ELF Header

ELF Header:

```
Magic: 7f 45 4c 46 01 01 01 00 00 00 00 00 00 00 00 00
Class: ELF32
Data: 2's complement, little endian
Version: 1 (current)
OS/ABI: UNIX - System V
ABI Version: 0
Type: EXEC (Executable file)
Machine: Intel 80386
Version: 0x1
Entry point address: 0x8048301
Start of program headers: 52 (bytes into file)
Start of section headers: 6180 (bytes into file)
Flags: 0x0
Size of this header: 52 (bytes)
Size of program headers: 32 (bytes)
Number of program headers: 9
Size of section headers: 40 (bytes)
Number of section headers: 31
Section header string table index: 28
```

p (2) Section Header (a)

Section Headers:

| [Nr] | Name | Type | Addr | Off | Size | ES | Flg | Lk | Inf | Al |
|------|--------------------|------------|----------|--------|--------|----|-----|----|-----|----|
| [0] | | NULL | 00000000 | 000000 | 000000 | 00 | | 0 | 0 | 0 |
| [1] | .interp | PROGBITS | 08048154 | 000154 | 000013 | 00 | A | 0 | 0 | 1 |
| [2] | .note.ABI-tag | NOTE | 08048168 | 000168 | 000020 | 00 | A | 0 | 0 | 4 |
| [3] | .note.gnu.build-id | NOTE | 08048188 | 000188 | 000024 | 00 | A | 0 | 0 | 4 |
| [4] | .gnu.hash | GNU_HASH | 080481ac | 0001ac | 000020 | 04 | A | 5 | 0 | 4 |
| [5] | .dynsym | DYNSYM | 080481cc | 0001cc | 000040 | 10 | A | 6 | 1 | 4 |
| [6] | .dynstr | STRTAB | 0804820c | 00020c | 000045 | 00 | A | 0 | 0 | 1 |
| [7] | .gnu.version | VERSYM | 08048252 | 000252 | 000008 | 02 | A | 5 | 0 | 2 |
| [8] | .gnu.version_r | VERNEED | 0804825c | 00025c | 000020 | 00 | A | 6 | 1 | 4 |
| [9] | .rel.dyn | REL | 0804827c | 00027c | 000008 | 08 | A | 5 | 0 | 4 |
| [10] | .rel.plt | REL | 08048284 | 000284 | 000008 | 08 | AI | 5 | 24 | 4 |
| [11] | .init | PROGBITS | 0804828c | 00028c | 000023 | 00 | AX | 0 | 0 | 4 |
| [12] | .plt | PROGBITS | 080482b0 | 0002b0 | 000020 | 04 | AX | 0 | 0 | 16 |
| [13] | .plt.got | PROGBITS | 080482d0 | 0002d0 | 000008 | 00 | AX | 0 | 0 | 8 |
| [14] | .text | PROGBITS | 080482e0 | 0002e0 | 0001a2 | 00 | AX | 0 | 0 | 16 |
| [15] | .fini | PROGBITS | 08048484 | 000484 | 000014 | 00 | AX | 0 | 0 | 4 |
| [16] | .rodata | PROGBITS | 08048498 | 000498 | 000008 | 00 | A | 0 | 0 | 4 |
| [17] | .eh_frame_hdr | PROGBITS | 080484a0 | 0004a0 | 000034 | 00 | A | 0 | 0 | 4 |
| [18] | .eh_frame | PROGBITS | 080484d4 | 0004d4 | 0000e0 | 00 | A | 0 | 0 | 4 |
| [19] | .init_array | INIT_ARRAY | 08049f08 | 000f08 | 000004 | 00 | WA | 0 | 0 | 4 |
| [20] | .fini_array | FINI_ARRAY | 08049f0c | 000f0c | 000004 | 00 | WA | 0 | 0 | 4 |

p (3) Section Header (b)

| | | | | | | | | | | |
|------|-----------|----------|----------|--------|--------|----|----|----|----|---|
| [21] | .jcr | PROGBITS | 08049f10 | 000f10 | 000004 | 00 | WA | 0 | 0 | 4 |
| [22] | .dynamic | DYNAMIC | 08049f14 | 000f14 | 0000e8 | 08 | WA | 6 | 0 | 4 |
| [23] | .got | PROGBITS | 08049ffc | 000ffc | 000004 | 04 | WA | 0 | 0 | 4 |
| [24] | .got.plt | PROGBITS | 0804a000 | 001000 | 000010 | 04 | WA | 0 | 0 | 4 |
| [25] | .data | PROGBITS | 0804a010 | 001010 | 000014 | 00 | WA | 0 | 0 | 4 |
| [26] | .bss | NOBITS | 0804a024 | 001024 | 000008 | 00 | WA | 0 | 0 | 4 |
| [27] | .comment | PROGBITS | 00000000 | 001024 | 000034 | 01 | MS | 0 | 0 | 1 |
| [28] | .shstrtab | STRTAB | 00000000 | 00171a | 00010a | 00 | | 0 | 0 | 1 |
| [29] | .symtab | SYMTAB | 00000000 | 001058 | 000490 | 10 | | 30 | 48 | 4 |
| [30] | .strtab | STRTAB | 00000000 | 0014e8 | 000232 | 00 | | 0 | 0 | 1 |

Key to Flags:

W (write), A (alloc), X (execute), M (merge), S (strings)

I (info), L (link order), G (group), T (TLS), E (exclude), x (unknown)

0 (extra OS processing required) o (OS specific), p (processor specific)

p (4) Program Header

Program Headers:

| Type | Offset | VirtAddr | PhysAddr | FileSiz | MemSiz | Flg | Align |
|--|----------|------------|------------|---------|---------|-----|--------|
| PHDR | 0x000034 | 0x08048034 | 0x08048034 | 0x00120 | 0x00120 | R E | 0x4 |
| INTERP | 0x000154 | 0x08048154 | 0x08048154 | 0x00013 | 0x00013 | R | 0x1 |
| [Requesting program interpreter: /lib/ld-linux.so.2] | | | | | | | |
| LOAD | 0x000000 | 0x08048000 | 0x08048000 | 0x005b4 | 0x005b4 | R E | 0x1000 |
| LOAD | 0x000f08 | 0x08049f08 | 0x08049f08 | 0x0011c | 0x00124 | RW | 0x1000 |
| DYNAMIC | 0x000f14 | 0x08049f14 | 0x08049f14 | 0x000e8 | 0x000e8 | RW | 0x4 |
| NOTE | 0x000168 | 0x08048168 | 0x08048168 | 0x00044 | 0x00044 | R | 0x4 |
| GNU_EH_FRAME | 0x0004a0 | 0x080484a0 | 0x080484a0 | 0x00034 | 0x00034 | R | 0x4 |
| GNU_STACK | 0x000000 | 0x00000000 | 0x00000000 | 0x00000 | 0x00000 | RW | 0x10 |
| GNU_RELRO | 0x000f08 | 0x08049f08 | 0x08049f08 | 0x000f8 | 0x000f8 | R | 0x1 |

p (5) Section to Segment Mapping

Section to Segment mapping:

Segment Sections...

00

01 .interp

02 .interp .note.ABI-tag .note.gnu.build-id .gnu.hash .dynsym .dynstr .gnu.v

03 .init_array .fini_array .jcr .dynamic .got .got.plt .data .bss

04 .dynamic

05 .note.ABI-tag .note.gnu.build-id

06 .eh_frame_hdr

07

08 .init_array .fini_array .jcr .dynamic .got

p (6) Dynamic Sections (a)

Dynamic section at offset 0xf14 contains 24 entries:

| Tag | Type | Name/Value |
|------------|----------------|-----------------------------|
| 0x00000001 | (NEEDED) | Shared library: [libc.so.6] |
| 0x0000000c | (INIT) | 0x804828c |
| 0x0000000d | (FINI) | 0x8048484 |
| 0x00000019 | (INIT_ARRAY) | 0x8049f08 |
| 0x0000001b | (INIT_ARRAYSZ) | 4 (bytes) |
| 0x0000001a | (FINI_ARRAY) | 0x8049f0c |
| 0x0000001c | (FINI_ARRAYSZ) | 4 (bytes) |
| 0x6ffffef5 | (GNU_HASH) | 0x80481ac |
| 0x00000005 | (STRTAB) | 0x804820c |
| 0x00000006 | (SYMTAB) | 0x80481cc |
| 0x0000000a | (STRSZ) | 69 (bytes) |
| 0x0000000b | (SYMENT) | 16 (bytes) |

p (7) Dynamic Sections (b)

Dynamic section at offset 0xf14 contains 24 entries:

| Tag | Type | Name/Value |
|-------------|--------------|------------|
| 0x00000003 | (PLTGOT) | 0x804a000 |
| 0x00000002 | (PLTRELSZ) | 8 (bytes) |
| 0x00000014 | (PLTREL) | REL |
| 0x00000017 | (JMPREL) | 0x8048284 |
| 0x00000011 | (REL) | 0x804827c |
| 0x00000012 | (RELSZ) | 8 (bytes) |
| 0x00000013 | (RELENT) | 8 (bytes) |
| 0x6fffffff | (VERNEED) | 0x804825c |
| 0x6fffffff | (VERNEEDNUM) | 1 |
| 0x6fffffff0 | (VERSYM) | 0x8048252 |
| 0x00000000 | (NULL) | 0x0 |

p (8) Misc Sections

Relocation section '.rel.dyn' at offset 0x27c contains 1 entries:

| Offset | Info | Type | Sym.Value | Sym. Name |
|----------|----------|----------------|-----------|----------------|
| 08049ffc | 00000106 | R_386_GLOB_DAT | 00000000 | __gmon_start__ |

Relocation section '.rel.plt' at offset 0x284 contains 1 entries:

| Offset | Info | Type | Sym.Value | Sym. Name |
|----------|----------|-----------------|-----------|-----------------------------|
| 0804a00c | 00000207 | R_386_JUMP_SLOT | 00000000 | __libc_start_main@GLIBC_2.0 |

The decoding of unwind sections for machine type Intel 80386 is not currently supported.

Symbol table '.dynsym' contains 4 entries:

| Num: | Value | Size | Type | Bind | Vis | Ndx | Name |
|------|----------|------|--------|--------|---------|-----|---------------------------------|
| 0: | 00000000 | 0 | NOTYPE | LOCAL | DEFAULT | UND | |
| 1: | 00000000 | 0 | NOTYPE | WEAK | DEFAULT | UND | __gmon_start__ |
| 2: | 00000000 | 0 | FUNC | GLOBAL | DEFAULT | UND | __libc_start_main@GLIBC_2.0 (2) |
| 3: | 0804849c | 4 | OBJECT | GLOBAL | DEFAULT | 16 | _IO_stdin_used |

p (9) Symbol Table (a)

Symbol table '.symtab' contains 73 entries:

| Num: | Value | Size | Type | Bind | Vis | Ndx | Name |
|------|----------|------|---------|-------|---------|-----|------|
| 0: | 00000000 | 0 | NOTYPE | LOCAL | DEFAULT | UND | |
| 1: | 08048154 | 0 | SECTION | LOCAL | DEFAULT | 1 | |
| 2: | 08048168 | 0 | SECTION | LOCAL | DEFAULT | 2 | |
| 3: | 08048188 | 0 | SECTION | LOCAL | DEFAULT | 3 | |
| 4: | 080481ac | 0 | SECTION | LOCAL | DEFAULT | 4 | |
| 5: | 080481cc | 0 | SECTION | LOCAL | DEFAULT | 5 | |
| 6: | 0804820c | 0 | SECTION | LOCAL | DEFAULT | 6 | |
| 7: | 08048252 | 0 | SECTION | LOCAL | DEFAULT | 7 | |
| 8: | 0804825c | 0 | SECTION | LOCAL | DEFAULT | 8 | |
| 9: | 0804827c | 0 | SECTION | LOCAL | DEFAULT | 9 | |
| 10: | 08048284 | 0 | SECTION | LOCAL | DEFAULT | 10 | |
| 11: | 0804828c | 0 | SECTION | LOCAL | DEFAULT | 11 | |
| 12: | 080482b0 | 0 | SECTION | LOCAL | DEFAULT | 12 | |
| 13: | 080482d0 | 0 | SECTION | LOCAL | DEFAULT | 13 | |
| 14: | 080482e0 | 0 | SECTION | LOCAL | DEFAULT | 14 | |
| 15: | 08048484 | 0 | SECTION | LOCAL | DEFAULT | 15 | |
| 16: | 08048498 | 0 | SECTION | LOCAL | DEFAULT | 16 | |
| 17: | 080484a0 | 0 | SECTION | LOCAL | DEFAULT | 17 | |
| 18: | 080484d4 | 0 | SECTION | LOCAL | DEFAULT | 18 | |
| 19: | 08049f08 | 0 | SECTION | LOCAL | DEFAULT | 19 | |
| 20: | 08049f0c | 0 | SECTION | LOCAL | DEFAULT | 20 | |

p (10) Symbol Table (b)

| | | | | | | | |
|-----|----------|---|---------|-------|---------|-----|---------------------------|
| 21: | 08049f10 | 0 | SECTION | LOCAL | DEFAULT | 21 | |
| 22: | 08049f14 | 0 | SECTION | LOCAL | DEFAULT | 22 | |
| 23: | 08049ffc | 0 | SECTION | LOCAL | DEFAULT | 23 | |
| 24: | 0804a000 | 0 | SECTION | LOCAL | DEFAULT | 24 | |
| 25: | 0804a010 | 0 | SECTION | LOCAL | DEFAULT | 25 | |
| 26: | 0804a024 | 0 | SECTION | LOCAL | DEFAULT | 26 | |
| 27: | 00000000 | 0 | SECTION | LOCAL | DEFAULT | 27 | |
| 28: | 00000000 | 0 | FILE | LOCAL | DEFAULT | ABS | crtstuff.c |
| 29: | 08049f10 | 0 | OBJECT | LOCAL | DEFAULT | 21 | __JCR_LIST__ |
| 30: | 08048340 | 0 | FUNC | LOCAL | DEFAULT | 14 | deregister_tm_clones |
| 31: | 08048370 | 0 | FUNC | LOCAL | DEFAULT | 14 | register_tm_clones |
| 32: | 080483b0 | 0 | FUNC | LOCAL | DEFAULT | 14 | __do_global_dtors_aux |
| 33: | 0804a024 | 1 | OBJECT | LOCAL | DEFAULT | 26 | completed.7200 |
| 34: | 08049f0c | 0 | OBJECT | LOCAL | DEFAULT | 20 | __do_global_dtors_aux_fin |
| 35: | 080483d0 | 0 | FUNC | LOCAL | DEFAULT | 14 | frame_dummy |
| 36: | 08049f08 | 0 | OBJECT | LOCAL | DEFAULT | 19 | __frame_dummy_init_array_ |
| 37: | 00000000 | 0 | FILE | LOCAL | DEFAULT | ABS | main.i |
| 38: | 00000000 | 0 | FILE | LOCAL | DEFAULT | ABS | swap.i |
| 39: | 00000000 | 0 | FILE | LOCAL | DEFAULT | ABS | crtstuff.c |
| 40: | 080485b0 | 0 | OBJECT | LOCAL | DEFAULT | 18 | __FRAME_END__ |

p (11) Symbol Table (c)

| | | | | | | | |
|-----|----------|----|--------|--------|---------|-----|---------------------------|
| 50: | 08048330 | 4 | FUNC | GLOBAL | HIDDEN | 14 | __x86.get_pc_thunk.bx |
| 51: | 0804a010 | 0 | NOTYPE | WEAK | DEFAULT | 25 | data_start |
| 52: | 0804a024 | 0 | NOTYPE | GLOBAL | DEFAULT | 25 | _edata |
| 53: | 0804a020 | 4 | OBJECT | GLOBAL | DEFAULT | 25 | p0 |
| 54: | 08048484 | 0 | FUNC | GLOBAL | DEFAULT | 15 | _fini |
| 55: | 0804a010 | 0 | NOTYPE | GLOBAL | DEFAULT | 25 | __data_start |
| 56: | 00000000 | 0 | NOTYPE | WEAK | DEFAULT | UND | __gmon_start__ |
| 57: | 0804a014 | 0 | OBJECT | GLOBAL | HIDDEN | 25 | __dso_handle |
| 58: | 0804849c | 4 | OBJECT | GLOBAL | DEFAULT | 16 | _IO_stdin_used |
| 59: | 00000000 | 0 | FUNC | GLOBAL | DEFAULT | UND | __libc_start_main@@GLIBC_ |
| 60: | 08048420 | 93 | FUNC | GLOBAL | DEFAULT | 14 | __libc_csu_init |
| 61: | 0804a02c | 0 | NOTYPE | GLOBAL | DEFAULT | 26 | _end |
| 62: | 08048301 | 0 | FUNC | GLOBAL | DEFAULT | 14 | _start |
| 63: | 08048498 | 4 | OBJECT | GLOBAL | DEFAULT | 16 | _fp_hw |
| 64: | 0804a018 | 8 | OBJECT | GLOBAL | DEFAULT | 25 | buf |
| 65: | 0804a024 | 0 | NOTYPE | GLOBAL | DEFAULT | 26 | __bss_start |
| 66: | 080482e0 | 33 | FUNC | GLOBAL | DEFAULT | 14 | main |
| 67: | 0804a028 | 4 | OBJECT | GLOBAL | DEFAULT | 26 | p1 |
| 68: | 00000000 | 0 | NOTYPE | WEAK | DEFAULT | UND | _Jv_RegisterClasses |
| 69: | 0804a024 | 0 | OBJECT | GLOBAL | HIDDEN | 25 | __TMC_END__ |
| 70: | 00000000 | 0 | NOTYPE | WEAK | DEFAULT | UND | _ITM_registerTMCloneTable |
| 71: | 08048400 | 32 | FUNC | GLOBAL | DEFAULT | 14 | swap |
| 72: | 0804828c | 0 | FUNC | GLOBAL | DEFAULT | 11 | _init |

p (12) Others

Histogram for '.gnu.hash' bucket list length (total of 2 buckets):

| Length | Number | % of total | Coverage |
|--------|--------|------------|----------|
| 0 | 1 | (50.0%) | |
| 1 | 1 | (50.0%) | 100.0% |

Version symbols section '.gnu.version' contains 4 entries:

```
Addr: 0000000008048252  Offset: 0x000252  Link: 5 (.dynsym)
000:  0 (*local*)          0 (*local*)          2 (GLIBC_2.0)        1 (*global*)
```

Version needs section '.gnu.version_r' contains 1 entries:

```
Addr: 0x000000000804825c  Offset: 0x00025c  Link: 6 (.dynstr)
000000:  Version: 1  File: libc.so.6  Cnt: 1
0x0010:  Name: GLIBC_2.0  Flags: none  Version: 2
```

Displaying notes found at file offset 0x00000168 with length 0x00000020:

| Owner | Data size | Description |
|------------------------|------------|----------------------------------|
| GNU | 0x00000010 | NT_GNU_ABI_TAG (ABI version tag) |
| OS: Linux, ABI: 2.6.32 | | |

Displaying notes found at file offset 0x00000188 with length 0x00000024:

| Owner | Data size | Description |
|--|------------|---|
| GNU | 0x00000014 | NT_GNU_BUILD_ID (unique build ID bitstring) |
| Build ID: 1574c15c3270ef63673147a7608a8d225665af50 | | |

gcc -llibrary (1)

- `-llibrary`
`-l library`
 - Search the library named `library` when linking
 - the second alternative with the library `-l library` as a separate argument is only for POSIX compliance and is not recommended
 - The `-l` option is passed directly to the linker by GCC.
 - the linker searches a standard list of directories for the library `library`
 - the directories searched include several standard system directories plus any that you specify with `-L`

man gcc

gcc -llibrary (2)

- `-llibrary`
 - `-l library`
 - static libraries are archives of object files, and have file names like `liblibrary.a`
 - some targets also support shared libraries, which typically have names like `liblibrary.so`
 - if both static and shared libraries are found, the linker gives preference to linking with the shared library unless the `-static` option is used.

`man gcc`

gcc -llibrary (3)

- `-llibrary`
 - l library
 - it makes a difference where in the command you write this option;
 - the linker searches and processes libraries and object files in the order they are specified.
 - Thus, `foo.o -lz bar.o` searches library `z` after file `foo.o` but before `bar.o`
 - if `bar.o` refers to functions in library `z`, those functions may not be loaded.

`man gcc`

- `-Ldir`
 - Add directory `dir` to the list of directories to be searched for `-l`.
- `-Lsearchdir`
 - `--library-path=searchdir`
 - add path `searchdir` to the list of paths that `ld` will search for archive libraries and `ld` control scripts.
 - you may use this option any number of times.
 - The directories are searched in the order in which they are specified on the command line.
 - Directories specified on the command line are searched before the default directories.

http://ftp.gnu.org/old-gnu/Manuals/ld-2.9.1/html_node/ld_3.html

- -Ldir
- -Lsearchdir
 - library-path=searchdir
 - All -L options apply to all -l options, regardless of the order in which the options appear.
 - the default set of paths searched (without using -L) depends on which emulation mode ld is using, and in some cases also on how it was configured.
 - The paths can also be specified in a link script with the SEARCH_DIR command.
 - Directories specified this way are searched at the point in which the linker script appears in the command line.

http://ftp.gnu.org/old-gnu/Manuals/ld-2.9.1/html_node/ld_3.html

- -Wl,/option/
 - pass option as an *option* to the linker.
 - if option contains *commas*, it is split into multiple options at the *commas*
 - use the *comma* (,) syntax to *pass* an argument to the option.
-Wl,-Map,output.map
passes -Map output.map to the linker.
 - When using the GNU linker, you can also get the same effect with =
-Wl,-Map=output.map

man gcc