Compilers Laboratory: CS39003

C++ Program Using Library Function

```
#include <iostream>
using namespace std;
int main()                                  // second0.c++
{
        cout << "My second program\n";
        return 0;
}
```

C++ Program Using System Call

```
#include <unistd.h>
#define LEN 19
int main()                                  // second1.c++
{
        char str[LEN] = "My second program\n";
        write(1, str, LEN);        // STDOUT_FILENO=1
        _exit(0) ;
}
```

Assembly Language Translation

```
        .file "second1.c++"
        .text
        .globl main
        .type main, @function
main:
.LFB0:
        .cfi_startproc
        pushq %rbp
        .cfi_def_cfa_offset 16
        .cfi_offset 6, -16
        movq %rsp, %rbp
        .cfi_def_cfa_register 6
        subq $32, %rsp                  # 32-byte stack-frame
        movq %fs:40, %rax               # Segment addressing
```

```
movq %rax, -8(%rbp)                 # M[rbp-8] <-- rax
xorl %eax, %eax                     # Clear eax
movl $1931508045, -32(%rbp)
        # 0111  0011  0010  0000  0111  1001  0100  1101
        # 73 20 79 4D - "s yM"
movl $1852793701, -28(%rbp)
        # 0110 1110 0110 1111 0110 0011 0110 0101
        # 6E 6F 63 65 - "noce"
movl $1919950948, -24(%rbp)
        # 0111 0010 0111 0000 0010 0000 0110 0100
        # 72 70 20 64 - "rp d"
movl $1634887535, -20(%rbp)
        # 0110 0001 0111 0010 0110 0111 0110 1111
        # 61 72 67 6F - "argo"
movw $2669, -16(%rbp)
        # 0000 1010 0110 1101
        # 0A 6D - "\nm"
```

```
        movb $0, -14(%rbp)
                # 0000 0000
                # 00 - '\0'
        leaq -32(%rbp), %rax            # rax <-- (rbp - 32) (str)
        movl $19, %edx                  # edx <-- 19 (LEN)
        movq %rax, %rsi                 # esi <-- rax (str)
        movl $1, %edi                   # edi <-- 1 (stdout)
        call write                      # call write
        movl $0, %edi                   # edi <-- 0
        call _exit                      # call exit
        .cfi_endproc
.LFE0:
        .size main, .-main
        .ident "GCC: (Ubuntu/Linaro 4.6.3-1ubuntu5) 4.6.3"
        .section .note.GNU-stack,"",@progbits
```

Using x86-64 Software Interrupt

```
#include <asm/unistd.h>
#include <syscall.h>
#define STDOUT_FILENO 1

.file "second3.S"
.section .rodata
L1:
        .string "My Second program\n"
L2:
.text
.globl _start
```

```
_start:
        movl $(SYS_write), %eax # eax <-- 1 (write)  parameters to write
        movq $(STDOUT_FILENO), %rdi          # rdi <-- 1 (stdout)
        movq $L1, %rsi          # rsi <-- starting address of string
        movq $(L2-L1), %rdx     # rdx <-- L2 - L1  string length
        syscall                 # software interrupt
                                # user process requesting OS for service
        movl $(SYS_exit), %eax  # eax <-- 60 (exit) parameters to exit
        movq $0, %rdi           # rdi <-- 0
        syscall                 # software interrupt
        ret                     # return
```

Preprocessor - Assembler - Linker

```
$ /lib/cpp  second3.S  second3.s
$ as  -o  second3.o  second3.s
$ ld  second3.o
$ ./a.out
My second program
```

Simple Library: Printing an Integer

```
#define BUFF 20                                   // filename → printInt.c++
void print_int(int n) {
        char buff[BUFF], zero='0';
        int i=0, j, k, bytes;
        if(n == 0) buff[i++]=zero;
        else{
                if(n < 0) {
                        buff[i++]='-';
                        n = -n;
                }
                while(n){
                        int dig = n%10;
                        buff[i++] = (char)(zero+dig);
                        n /= 10;
                }
```

```
                if(buff[0] == '-') j = 1;
                else j = 0;
                k=i-1;
                while(j<k){
                        char temp=buff[j];
                        buff[j++] = buff[k];
                        buff[k--] = temp;
                }
        }
        buff[i]='\n';
        bytes = i+1;
        __asm__ __volatile__ (
                "movl $1, %%eax \n\t"
                "movq $1, %%rdi \n\t"
                "syscall \n\t"
                :
                :"S"(buff), "d"(bytes)
        ) ; // $4: write, $1: on stdin
}
```

Printing an Integer

```
#ifndef _MYPRINTINT_H                    //printInt.h
#define _MYPRINTINT_H
void print_int(int);
#endif
```

```
#include <iostream>
using namespace std;
#include "printInt.h"
int main()                               // mainPrintInt.c++
{
        int n;
        cout << "Enter an integer: ";
        cin >> n;
        print_int(n);
        return 0;
}
```

Creating a Library

```
$ c++ -Wall -c  printInt.c++
$ ar  -rcs  libprintInt.a  printInt.o
$ c++  -Wall -c  mainPrintInt.c++
$ c++  mainPrintInt.o  -L.  -lprintInt
$ ./a.out
Enter an integer: -123
-123
$
```

Make file

An utility program that automatically decides which part of a large software is required to be recompiled.

Target: Prerequisites

Command

- **Target:** name of a file generated by a program e.g. main.o or certain action e.g. clean.

- **Prerequisites:** files required to create the target e.g. main.c++, xyz.h etc.

- **Command:** that creates the target e.g. c++ -Wall main.c++.

A Simple Makefile

```
a.out:    mainPrintInt.o libprintInt.a
                c++ mainPrintInt.o -L. –lprintInt

mainPrintInt.o:  mainPrintInt.c++ printInt.h
                        c++ -Wall -c mainPrintInt.c++

libprintInt.a:      printInt.o
                        ar -rcs libprintInt.a printInt.o

printInt.o:         printInt.c++ printInt.h
                        c++ -Wall -c printInt.c++

clean:
        rm a.out mainPrintInt.o libprintInt.a printInt.o
```

Usage of Makefile

$ make clean

rm a.out mainPrintInt.o libprintInt.a printInt.o

$ make

c++ -Wall -c mainPrintInt.c++

c++ -Wall -c printInt.c++

ar -rcs libprintInt.a printInt.o

c++ mainPrintInt.o -L. –lprintInt

Creating Library

```
$ cp  libprintInt.a  /usr/lib
$ c++  mainPrintInt.o  -lprintInt
```

Creating Shared Library

Following are steps for creating a shared library:

```
$ c++ -Wall -fPIC -c printInt.c
$ c++ -shared -Wl,-soname,libprintInt.so -o libprintInt.so printInt.o
```

Perform the following steps as superuser.

```
$ cp libprintInt.so /usr/lib/
$ ldconfig -n /usr/lib/
```

The soft-link libprint int.so.1 is created under /usr/lib. Final compilation:

```
$ c++ mainPrintInt.o -lprintInt
```

The new ./a.out does not contain the code of print_int(). But it contains code for the corresponding plt (procedure linkage table).

Dissembled second3.o

$ objdump -d second3.o

second3.o: file format elf64-x86-64

Disassembly of section .text:

0000000000000000 <_start>:

```
  0:    b8 01 00 00 00          mov   $0x1,%eax
  5:    48 c7 c7 01 00 00 00    mov   $0x1,%rdi
  c:    48 c7 c6 00 00 00 00    mov   $0x0,%rsi
 13:    48 c7 c2 13 00 00 00    mov   $0x13,%rdx
 1a:    0f 05                   syscall
 1c:    b8 3c 00 00 00          mov   $0x3c,%eax
 21:    48 c7 c7 00 00 00 00    mov   $0x0,%rdi
 28:    0f 05                   syscall
 2a:    c3                      retq
```

Dissembled a.out

$ objdump -d a.out

a.out: file format elf64-x86-64

Disassembly of section .text:

0000000000400078 <_start>:

```
  400078:   b8 01 00 00 00          mov   $0x1,%eax
  40007d:   48 c7 c7 01 00 00 00    mov   $0x1,%rdi
  400084:   48 c7 c6 a3 00 40 00    mov   $0x4000a3,%rsi
  40008b:   48 c7 c2 13 00 00 00    mov   $0x13,%rdx
  400092:   0f 05                   syscall
  400094:   b8 3c 00 00 00          mov   $0x3c,%eax
  400099:   48 c7 c7 00 00 00 00    mov   $0x0,%rdi
  4000a0:   0f 05                   syscall
  4000a2:   c3                      retq
```