RV Day 1 – Introduction to RISC-V and GNU compiler toolchain

RV-D1SK1 – Introduction to RISC-V basic keywords

RV_D1SK1_L1_Introduction

- C-program – Assembly language – Machine language [binary language] – Layout.
- RISC-V Architecture – Implementation – Layout

RV_D1SK1_L2_From Apps to Hardware

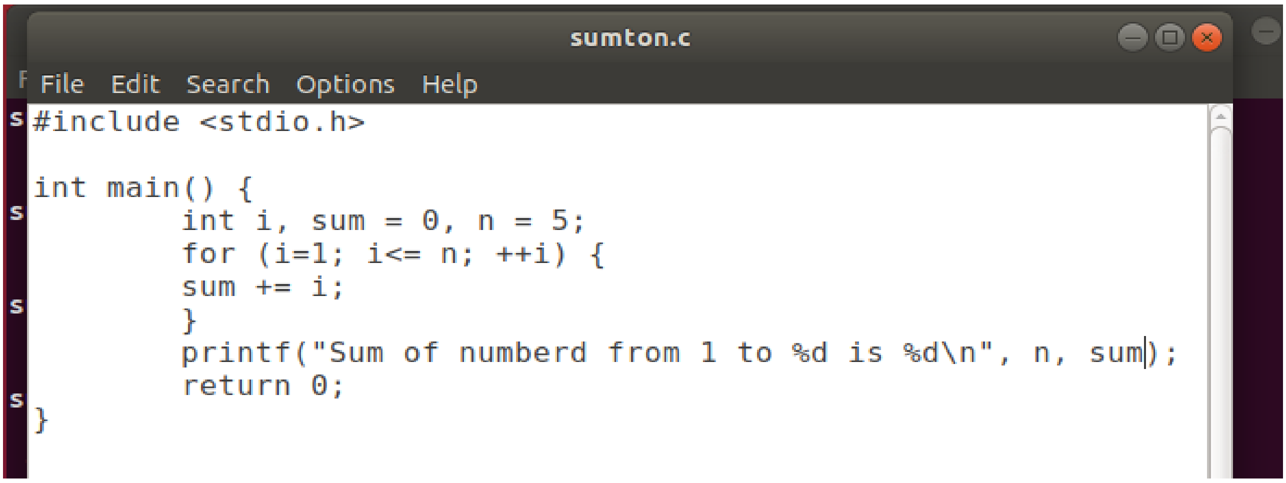
- Application software or Apps – System Software – Hardware
- Inside System software = OS-Compiler-Assembler
- Languages like C, C++, VB, Java to Compiler to Instruction set in .exe file then to Assembler [hexadecimal] to Binary language to Hardware.
- Abstract interface instruction set architecture or architecture of computer this Instruction set acts as an Abstract interface between Languages and Hardware.
- RTL Implementation of instruction set then this RTL is getting synthesis in form of gates, flip-flops etc. followed by physical design implementation of the synthesis netlist to Hardware.

RV_D1SK1_L3_Detailed Description of Courses content

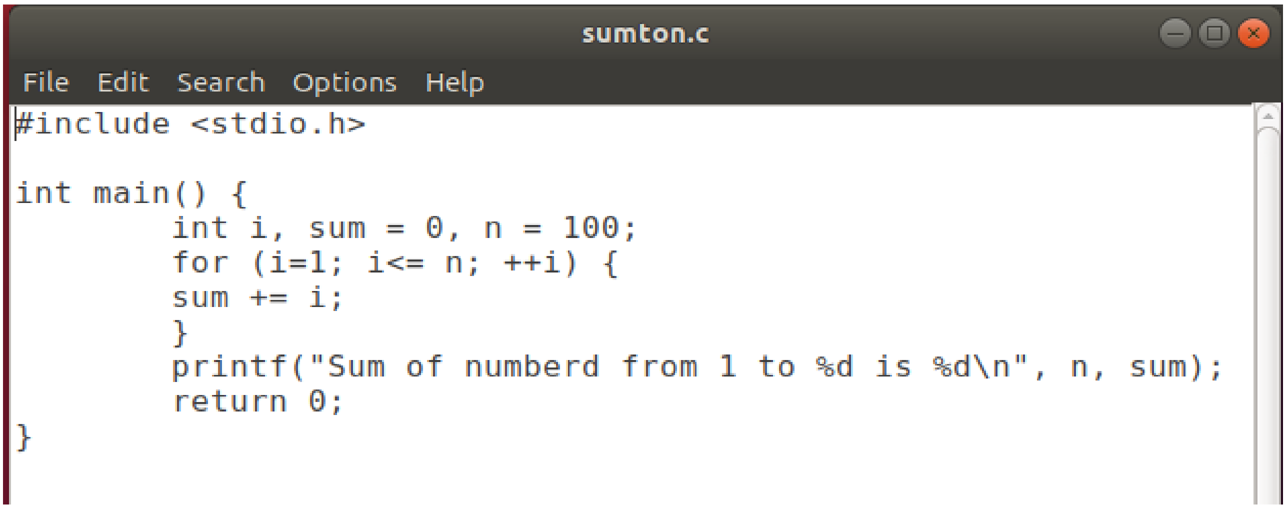
- Basic instruction:
    - Pseudo instructions: mv, li, ret
    - Base integer instruction RV641[risc-v 64bit integer]
    - Multiply extension RV64M: Multiplication & division function: mulw, divw.
    - Single & double precision floating point extension RV64F & RV64D: flw-floating point. [F=single & D=double precision floating point.]
    - Application binary interface [ABI].
    - Memory allocation & stack pointer.

RV_D1SK2 – Lab work for RISC-V software toolchain

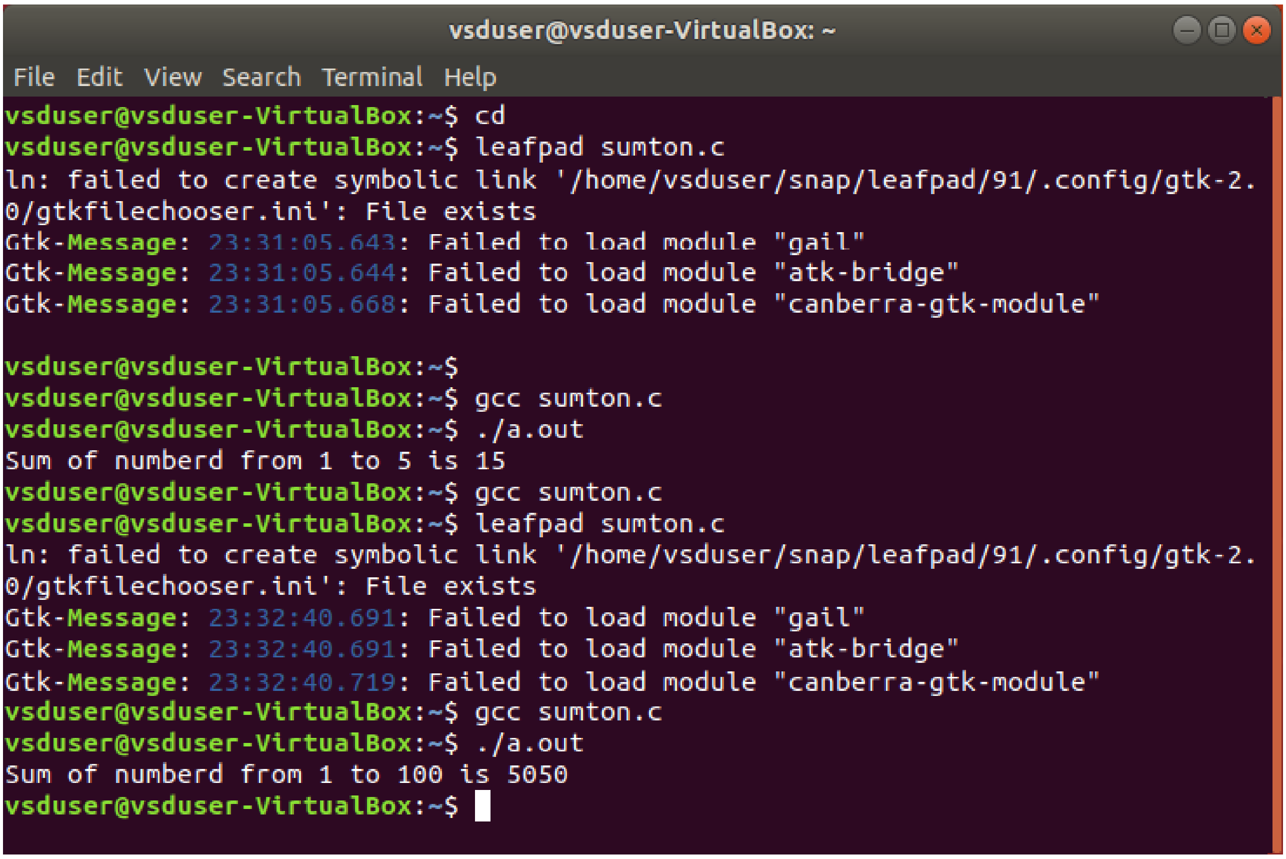
RV_D1SK2_L1_C Program to Compute Sum from 1 to N



```
#include <stdio.h>

int main() {
        int i, sum = 0, n = 5;
        for (i=1; i<= n; ++i) {
        sum += i;
        }
        printf("Sum of numberd from 1 to %d is %d\n", n, sum);
        return 0;
}
```

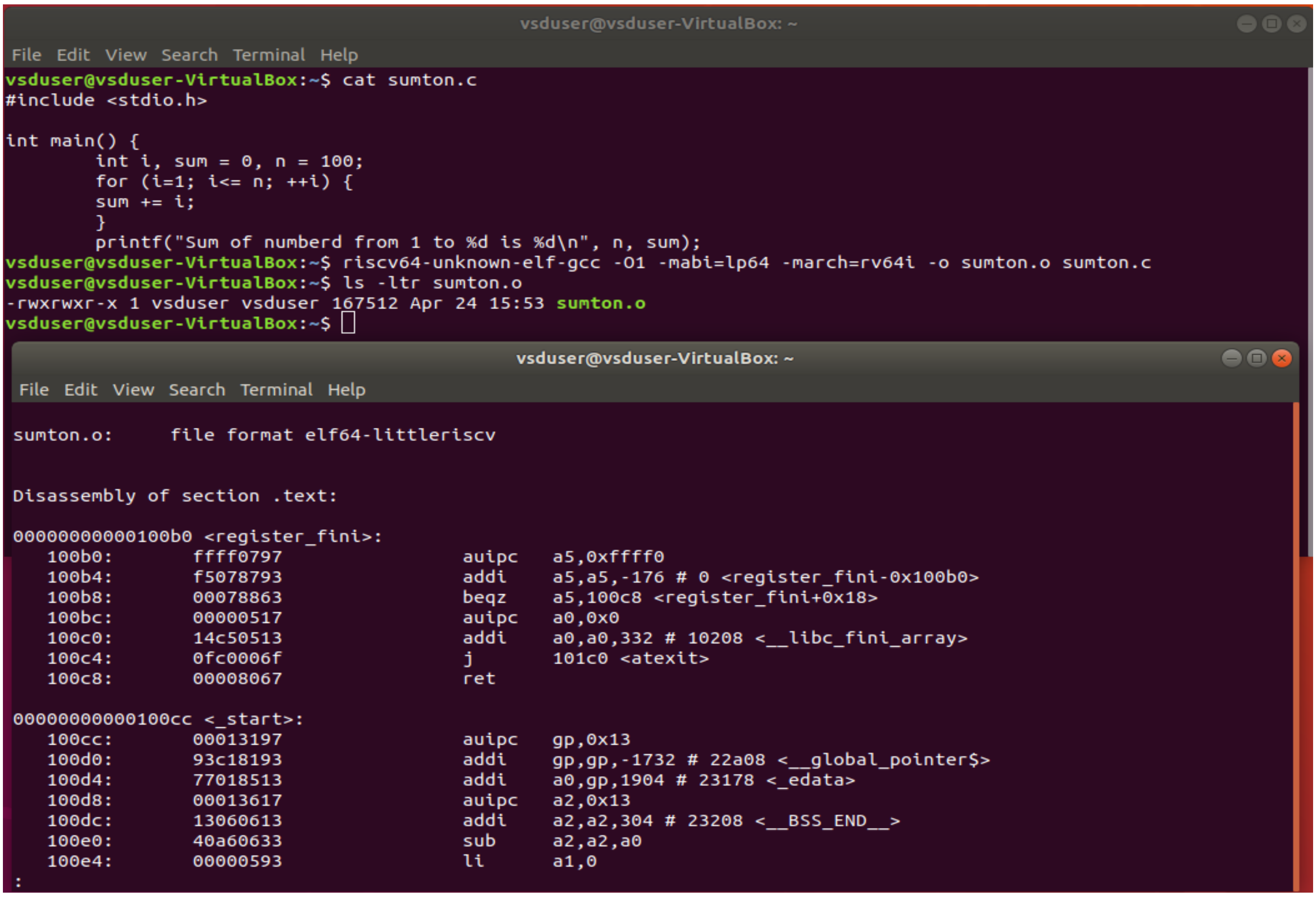


```
#include <stdio.h>

int main() {
        int i, sum = 0, n = 100;
        for (i=1; i<= n; ++i) {
        sum += i;
        }
        printf("Sum of numberd from 1 to %d is %d\n", n, sum);
        return 0;
}
```


vsduser@vsduser-VirtualBox: ~
File Edit View Search Terminal Help

```
vsduser@vsduser-VirtualBox:~$ cd
vsduser@vsduser-VirtualBox:~$ leafpad sumton.c
ln: failed to create symbolic link '/home/vsduser/snap/leafpad/91/.config/gtk-2.
0/gtkfilechooser.ini': File exists
Gtk-Message: 23:31:05.643: Failed to load module "gail"
Gtk-Message: 23:31:05.644: Failed to load module "atk-bridge"
Gtk-Message: 23:31:05.668: Failed to load module "canberra-gtk-module"

vsduser@vsduser-VirtualBox:~$
vsduser@vsduser-VirtualBox:~$ gcc sumton.c
vsduser@vsduser-VirtualBox:~$ ./a.out
Sum of numberd from 1 to 5 is 15
vsduser@vsduser-VirtualBox:~$ gcc sumton.c
vsduser@vsduser-VirtualBox:~$ leafpad sumton.c
ln: failed to create symbolic link '/home/vsduser/snap/leafpad/91/.config/gtk-2.
0/gtkfilechooser.ini': File exists
Gtk-Message: 23:32:40.691: Failed to load module "gail"
Gtk-Message: 23:32:40.691: Failed to load module "atk-bridge"
Gtk-Message: 23:32:40.719: Failed to load module "canberra-gtk-module"
vsduser@vsduser-VirtualBox:~$ gcc sumton.c
vsduser@vsduser-VirtualBox:~$ ./a.out
Sum of numberd from 1 to 100 is 5050
vsduser@vsduser-VirtualBox:~$
```

RV_D1SK2_L2_RISCV GCC compile And Disassemble

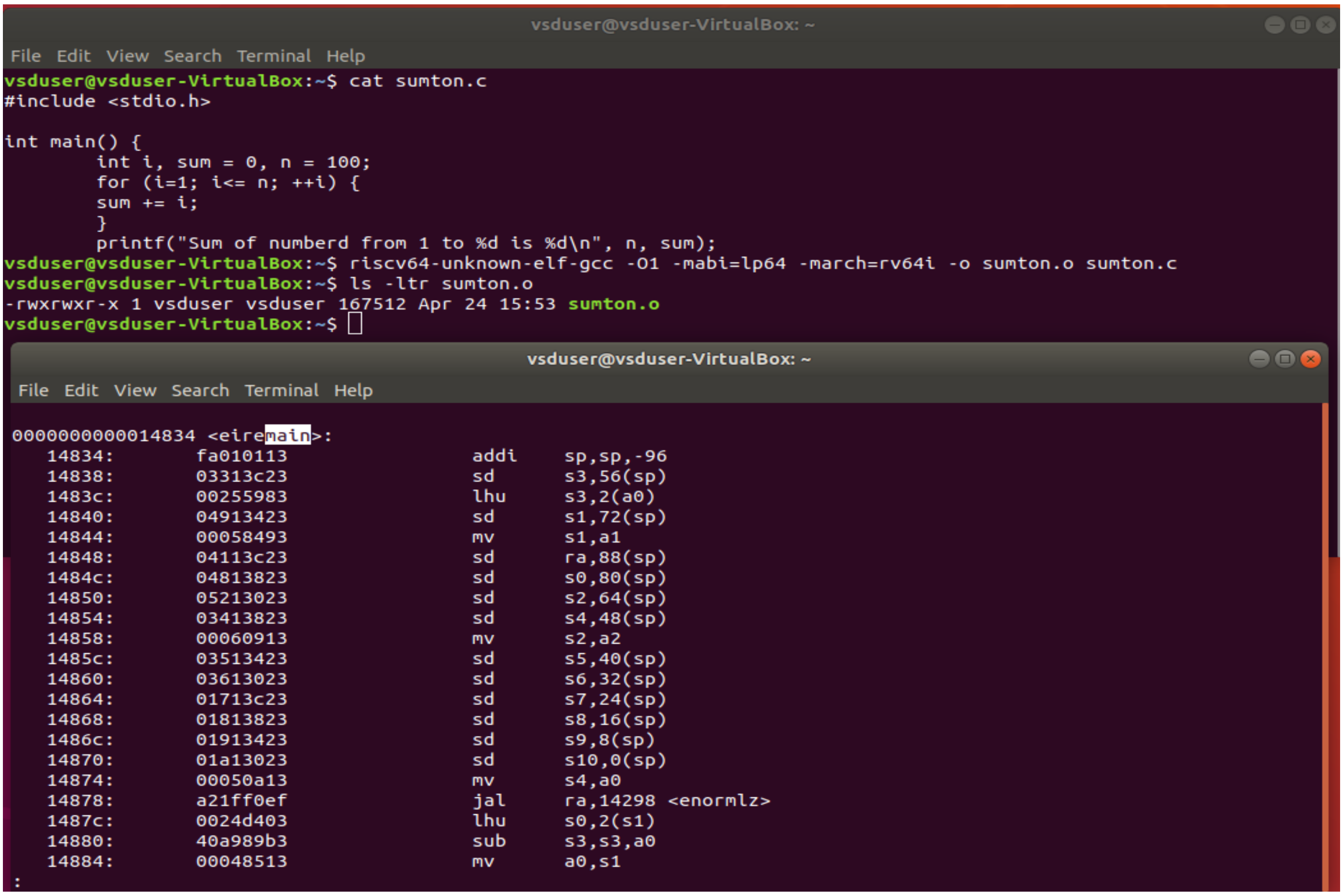

vsduser@vsduser-VirtualBox: ~
File Edit View Search Terminal Help

```
vsduser@vsduser-VirtualBox:~$ cat sumton.c
#include <stdio.h>

int main() {
        int i, sum = 0, n = 100;
        for (i=1; i<= n; ++i) {
        sum += i;
        }
        printf("Sum of numberd from 1 to %d is %d\n", n, sum);
vsduser@vsduser-VirtualBox:~$ riscv64-unknown-elf-gcc -O1 -mabi=lp64 -march=rv64i -o sumton.o sumton.c
vsduser@vsduser-VirtualBox:~$ ls -ltr sumton.o
-rwxrwxr-x 1 vsduser vsduser 167512 Apr 24 15:53 sumton.o
vsduser@vsduser-VirtualBox:~$
```

vsduser@vsduser-VirtualBox: ~
File Edit View Search Terminal Help

```
sumton.o:     file format elf64-littleriscv


Disassembly of section .text:

00000000000100b0 <register_fini>:
   100b0:       ffff0797                auipc   a5,0xffff0
   100b4:       f5078793                addi    a5,a5,-176 # 0 <register_fini-0x100b0>
   100b8:       00078863                beqz    a5,100c8 <register_fini+0x18>
   100bc:       00000517                auipc   a0,0x0
   100c0:       14c50513                addi    a0,a0,332 # 10208 <__libc_fini_array>
   100c4:       0fc0006f                j       101c0 <atexit>
   100c8:       00008067                ret

00000000000100cc <_start>:
   100cc:       00013197                auipc   gp,0x13
   100d0:       93c18193                addi    gp,gp,-1732 # 22a08 <__global_pointer$>
   100d4:       77018513                addi    a0,gp,1904 # 23178 <_edata>
   100d8:       00013617                auipc   a2,0x13
   100dc:       13060613                addi    a2,a2,304 # 23208 <__BSS_END__>
   100e0:       40a60633                sub     a2,a2,a0
   100e4:       00000593                li      a1,0
:
```

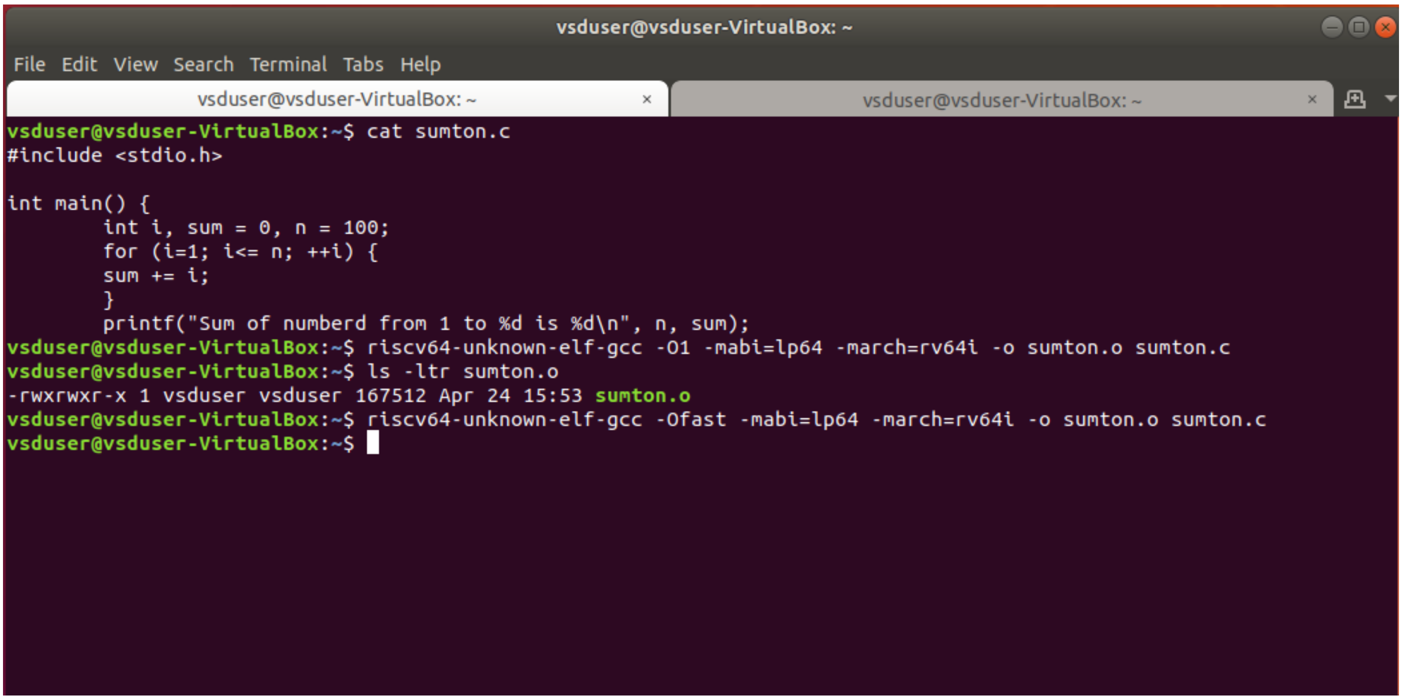
riscv64-unknown-elf-objdump -d sumton.o | less


vsduser@vsduser-VirtualBox: ~
File Edit View Search Terminal Help

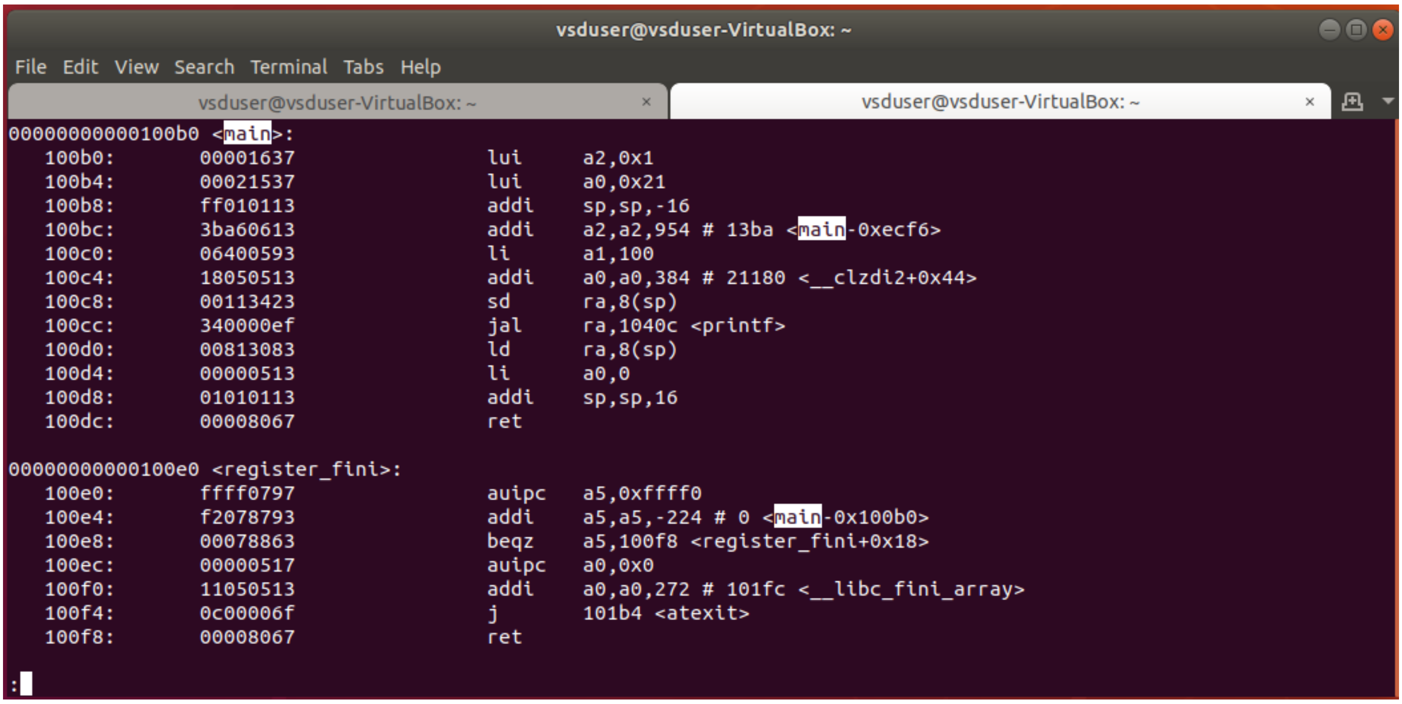
```
vsduser@vsduser-VirtualBox:~$ cat sumton.c
#include <stdio.h>

int main() {
        int i, sum = 0, n = 100;
        for (i=1; i<= n; ++i) {
        sum += i;
        }
        printf("Sum of numberd from 1 to %d is %d\n", n, sum);
vsduser@vsduser-VirtualBox:~$ riscv64-unknown-elf-gcc -O1 -mabi=lp64 -march=rv64i -o sumton.o sumton.c
vsduser@vsduser-VirtualBox:~$ ls -ltr sumton.o
-rwxrwxr-x 1 vsduser vsduser 167512 Apr 24 15:53 sumton.o
vsduser@vsduser-VirtualBox:~$
```

vsduser@vsduser-VirtualBox: ~
File Edit View Search Terminal Help

```
0000000000014834 <eiremain>:
   14834:       fa010113                addi    sp,sp,-96
   14838:       03313c23                sd      s3,56(sp)
   1483c:       00255983                lhu     s3,2(a0)
   14840:       04913423                sd      s1,72(sp)
   14844:       00058493                mv      s1,a1
   14848:       04113c23                sd      ra,88(sp)
   1484c:       04813823                sd      s0,80(sp)
   14850:       05213023                sd      s2,64(sp)
   14854:       03413823                sd      s4,48(sp)
   14858:       00060913                mv      s2,a2
   1485c:       03513423                sd      s5,40(sp)
   14860:       03613023                sd      s6,32(sp)
   14864:       01713c23                sd      s7,24(sp)
   14868:       01813823                sd      s8,16(sp)
   1486c:       01913423                sd      s9,8(sp)
   14870:       01a13023                sd      s10,0(sp)
   14874:       00050a13                mv      s4,a0
   14878:       a21ff0ef                jal     ra,14298 <enormlz>
   1487c:       0024d403                lhu     s0,2(s1)
   14880:       40a989b3                sub     s3,s3,a0
   14884:       00048513                mv      a0,s1
:
```


vsduser@vsduser-VirtualBox: ~
File Edit View Search Terminal Tabs Help
vsduser@vsduser-VirtualBox: ~
vsduser@vsduser-VirtualBox: ~

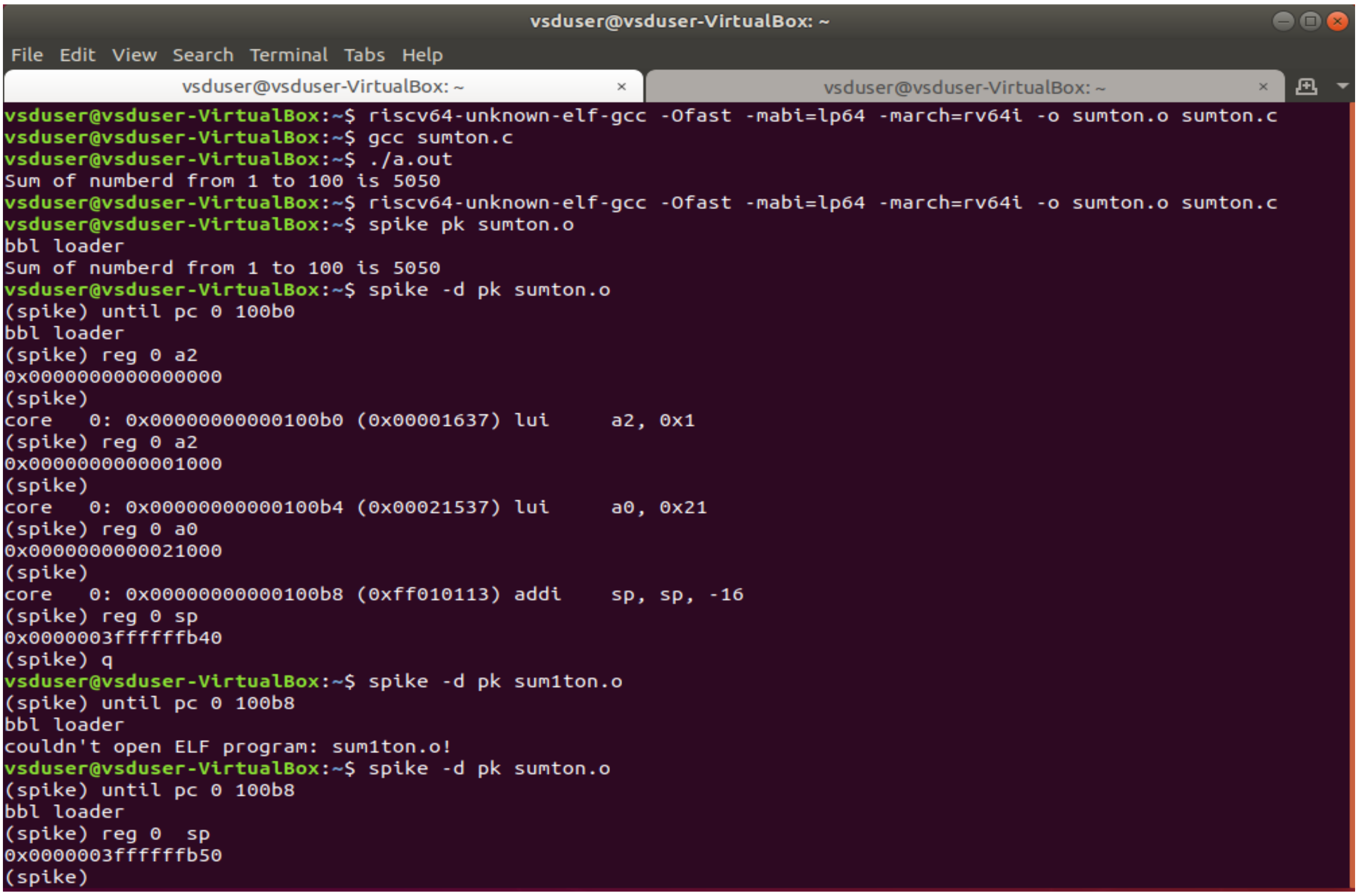
```
vsduser@vsduser-VirtualBox:~$ cat sumton.c
#include <stdio.h>

int main() {
        int i, sum = 0, n = 100;
        for (i=1; i<= n; ++i) {
        sum += i;
        }
        printf("Sum of numberd from 1 to %d is %d\n", n, sum);
vsduser@vsduser-VirtualBox:~$ riscv64-unknown-elf-gcc -O1 -mabi=lp64 -march=rv64i -o sumton.o sumton.c
vsduser@vsduser-VirtualBox:~$ ls -ltr sumton.o
-rwxrwxr-x 1 vsduser vsduser 167512 Apr 24 15:53 sumton.o
vsduser@vsduser-VirtualBox:~$ riscv64-unknown-elf-gcc -Ofast -mabi=lp64 -march=rv64i -o sumton.o sumton.c
vsduser@vsduser-VirtualBox:~$ 
```


vsduser@vsduser-VirtualBox: ~
File Edit View Search Terminal Tabs Help
vsduser@vsduser-VirtualBox: ~
vsduser@vsduser-VirtualBox: ~

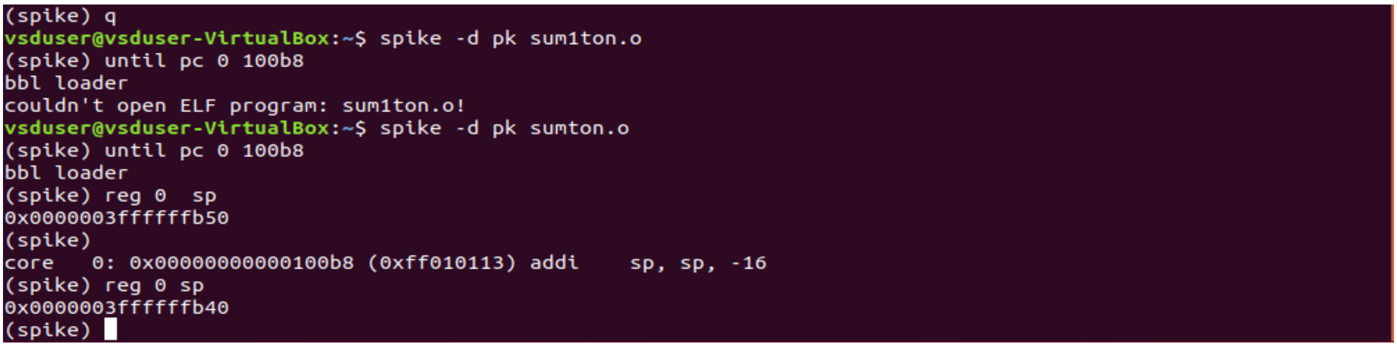
```
00000000000100b0 <main>:
   100b0:       00001637                lui     a2,0x1
   100b4:       00021537                lui     a0,0x21
   100b8:       ff010113                addi    sp,sp,-16
   100bc:       3ba60613                addi    a2,a2,954 # 13ba <main-0xecf6>
   100c0:       06400593                li      a1,100
   100c4:       18050513                addi    a0,a0,384 # 21180 <__clzdi2+0x44>
   100c8:       00113423                sd      ra,8(sp)
   100cc:       340000ef                jal     ra,1040c <printf>
   100d0:       00813083                ld      ra,8(sp)
   100d4:       00000513                li      a0,0
   100d8:       01010113                addi    sp,sp,16
   100dc:       00008067                ret

00000000000100e0 <register_fini>:
   100e0:       ffff0797                auipc   a5,0xffff0
   100e4:       f2078793                addi    a5,a5,-224 # 0 <main-0x100b0>
   100e8:       00078863                beqz    a5,100f8 <register_fini+0x18>
   100ec:       00000517                auipc   a0,0x0
   100f0:       11050513                addi    a0,a0,272 # 101fc <__libc_fini_array>
   100f4:       0c00006f                j       101b4 <atexit>
   100f8:       00008067                ret

:
```

12 instructions

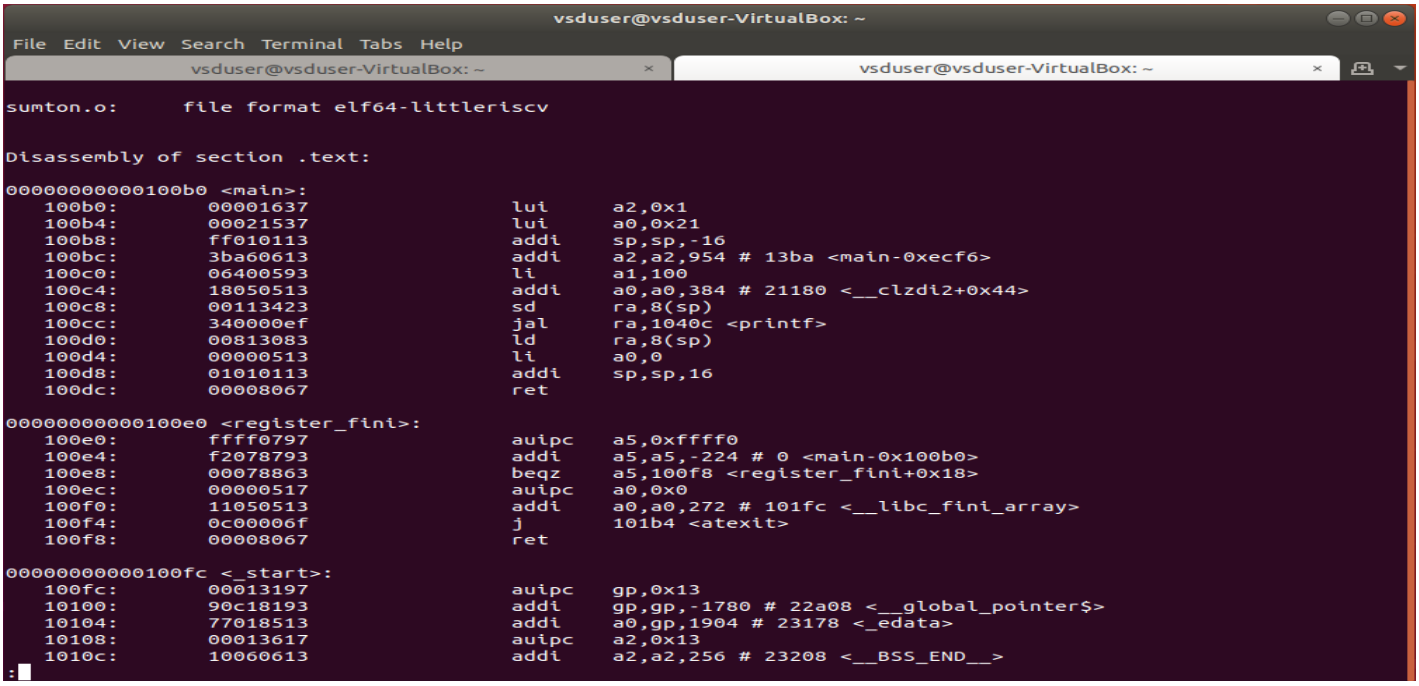
RV_D1SK2_L3_Spike Simulation and Debug


vsduser@vsduser-VirtualBox: ~
File Edit View Search Terminal Tabs Help
vsduser@vsduser-VirtualBox: ~
vsduser@vsduser-VirtualBox: ~

```
vsduser@vsduser-VirtualBox:~$ riscv64-unknown-elf-gcc -Ofast -mabi=lp64 -march=rv64i -o sumton.o sumton.c
vsduser@vsduser-VirtualBox:~$ gcc sumton.c
vsduser@vsduser-VirtualBox:~$ ./a.out
Sum of numberd from 1 to 100 is 5050
vsduser@vsduser-VirtualBox:~$ riscv64-unknown-elf-gcc -Ofast -mabi=lp64 -march=rv64i -o sumton.o sumton.c
vsduser@vsduser-VirtualBox:~$ spike pk sumton.o
bbl loader
Sum of numberd from 1 to 100 is 5050
vsduser@vsduser-VirtualBox:~$ spike -d pk sumton.o
(spike) until pc 0 100b0
bbl loader
(spike) reg 0 a2
0x0000000000000000
(spike)
core   0: 0x00000000000100b0 (0x00001637) lui     a2, 0x1
(spike) reg 0 a2
0x0000000000001000
(spike)
core   0: 0x00000000000100b4 (0x00021537) lui     a0, 0x21
(spike) reg 0 a0
0x0000000000021000
(spike)
core   0: 0x00000000000100b8 (0xff010113) addi    sp, sp, -16
(spike) reg 0 sp
0x0000003ffffffb40
(spike) q
vsduser@vsduser-VirtualBox:~$ spike -d pk sum1ton.o
(spike) until pc 0 100b8
bbl loader
couldn't open ELF program: sum1ton.o!
vsduser@vsduser-VirtualBox:~$ spike -d pk sumton.o
(spike) until pc 0 100b8
bbl loader
(spike) reg 0  sp
0x0000003ffffffb50
(spike)
```



```
(spike) q
vsduser@vsduser-VirtualBox:~$ spike -d pk sum1ton.o
(spike) until pc 0 100b8
bbl loader
couldn't open ELF program: sum1ton.o!
vsduser@vsduser-VirtualBox:~$ spike -d pk sumton.o
(spike) until pc 0 100b8
bbl loader
(spike) reg 0  sp
0x0000003ffffffb50
(spike)
core   0: 0x00000000000100b8 (0xff010113) addi    sp, sp, -16
(spike) reg 0 sp
0x0000003ffffffb40
(spike)
```


vsduser@vsduser-VirtualBox: ~
File Edit View Search Terminal Tabs Help
vsduser@vsduser-VirtualBox: ~
vsduser@vsduser-VirtualBox: ~

```
sumton.o:     file format elf64-littleriscv


Disassembly of section .text:

00000000000100b0 <main>:
   100b0:       00001637                lui     a2,0x1
   100b4:       00021537                lui     a0,0x21
   100b8:       ff010113                addi    sp,sp,-16
   100bc:       3ba60613                addi    a2,a2,954 # 13ba <main-0xecf6>
   100c0:       06400593                li      a1,100
   100c4:       18050513                addi    a0,a0,384 # 21180 <__clzdi2+0x44>
   100c8:       00113423                sd      ra,8(sp)
   100cc:       340000ef                jal     ra,1040c <printf>
   100d0:       00813083                ld      ra,8(sp)
   100d4:       00000513                li      a0,0
   100d8:       01010113                addi    sp,sp,16
   100dc:       00008067                ret

00000000000100e0 <register_fini>:
   100e0:       ffff0797                auipc   a5,0xffff0
   100e4:       f2078793                addi    a5,a5,-224 # 0 <main-0x100b0>
   100e8:       00078863                beqz    a5,100f8 <register_fini+0x18>
   100ec:       00000517                auipc   a0,0x0
   100f0:       11050513                addi    a0,a0,272 # 101fc <__libc_fini_array>
   100f4:       0c00006f                j       101b4 <atexit>
   100f8:       00008067                ret

00000000000100fc <_start>:
   100fc:       00013197                auipc   gp,0x13
   10100:       90c18193                addi    gp,gp,-1780 # 22a08 <__global_pointer$>
   10104:       77018513                addi    a0,gp,1904 # 23178 <_edata>
   10108:       00013617                auipc   a2,0x13
   1010c:       10060613                addi    a2,a2,256 # 23208 <__BSS_END__>
:
```

RV_D1SK3 – Integer number representation

RV_D1SK3_L1_64-bit Number system for Unsigned Numbers

- The 64-bit number is called the Double word in the terms of processer language.
- 32 bit is called as word.
- Group of 8 bits is called a Byte.
- Total 4 bytes form a word and total of 8 bytes form a Doubleword.
- {8-bits = byte, 4-byte = word, 2-words or 8-bytes = doubleword}
- 2-bit: No. of patterns 2^2:4 = '0' to '(2^2-1)' = 0 to 3
- 3-bit: No. of patterns 2^3:8 = '0' to '(2^3-1)' = 0 to 7
- 4-bit: No. of patterns 2^4:16 = '0' to '(2^4-1)' = 0 to 15
- 64-bit represented by RV64: 2^{64} = '0' to '(2^{64} – 1)'

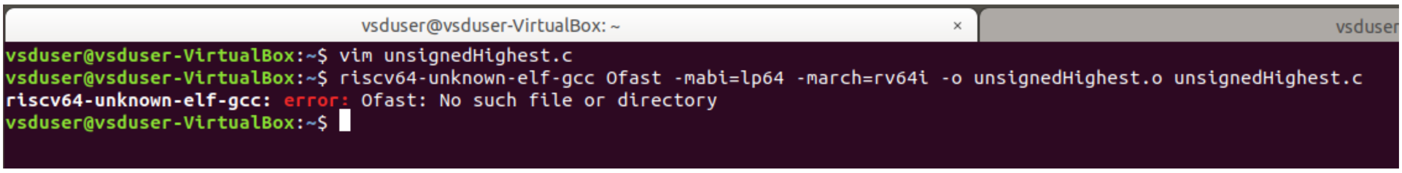
Range of numbers that can be represented by RV64:

- Highest number of RV64 :
  64bit $(11111111)_{bin}$ = $(18,446,744,073,709,551,615)_{dec}$.
- Lowest number of RV64 :
  64bit $(00000000)_{bin}$ = $(00,000,000,000,000,000,000)_{dec}$.
- Unsigned numbers or Positive numbers.

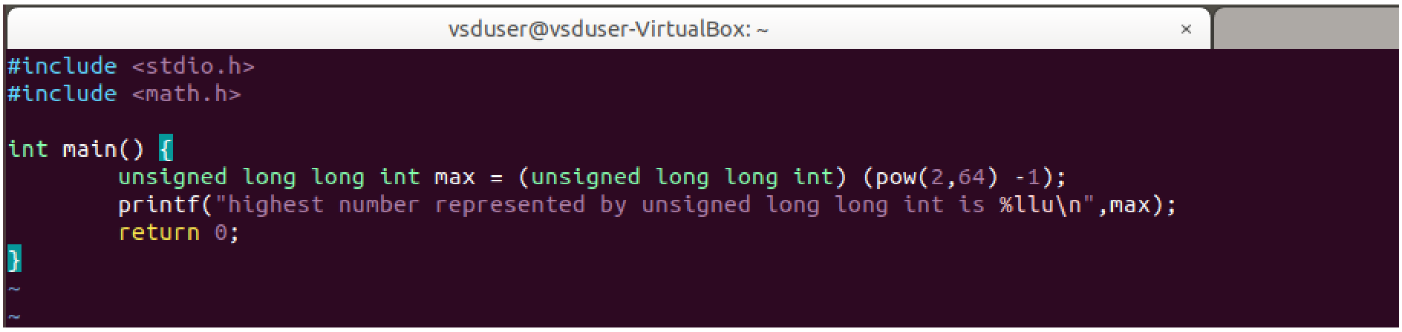
RV_D1SK3_L2_64-bit Number system for Signed Numbers

- To get negative number we have to get the Binary rep of the number then invert this number ; finding the two's complement and then add '1' hence we get the output .
- We observe that,
  The MSB of Positive number is '0' .
  The MSB of Negative number is '1' .
- RISC-V doubleword can represent '0' to'(2^{63} - 1)' positive & '-1' to '-2^{63}' negative numbers.
- Instructions which operate on these kind of instruction are called as Base integer Instructions RV64I.

RV_D1SK3_L3_ Lab for Unsigned and Signed Numbers



```
vsduser@vsduser-VirtualBox:~$ vim unsignedHighest.c
vsduser@vsduser-VirtualBox:~$ riscv64-unknown-elf-gcc Ofast -mabi=lp64 -march=rv64i -o unsignedHighest.o unsignedHighest.c
riscv64-unknown-elf-gcc: error: Ofast: No such file or directory
vsduser@vsduser-VirtualBox:~$ 
```



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

int main() {
        unsigned long long int max = (unsigned long long int) (pow(2,64) -1);
        printf("highest number represented by unsigned long long int is %llu\n",max);
        return 0;
}
~
~
```

Date Type	Memory(byte)	Format specifier
Unsigned int	4	%u
Int	4	%d
Unsigned long long int	8	%llu
long long int	8	%lld