CS 377 Project Report

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We have built an experimental OS (eXpOS by nitc) in 10 stages. Code files of all the assignment questions of all stages have been uploaded in the google classroom.

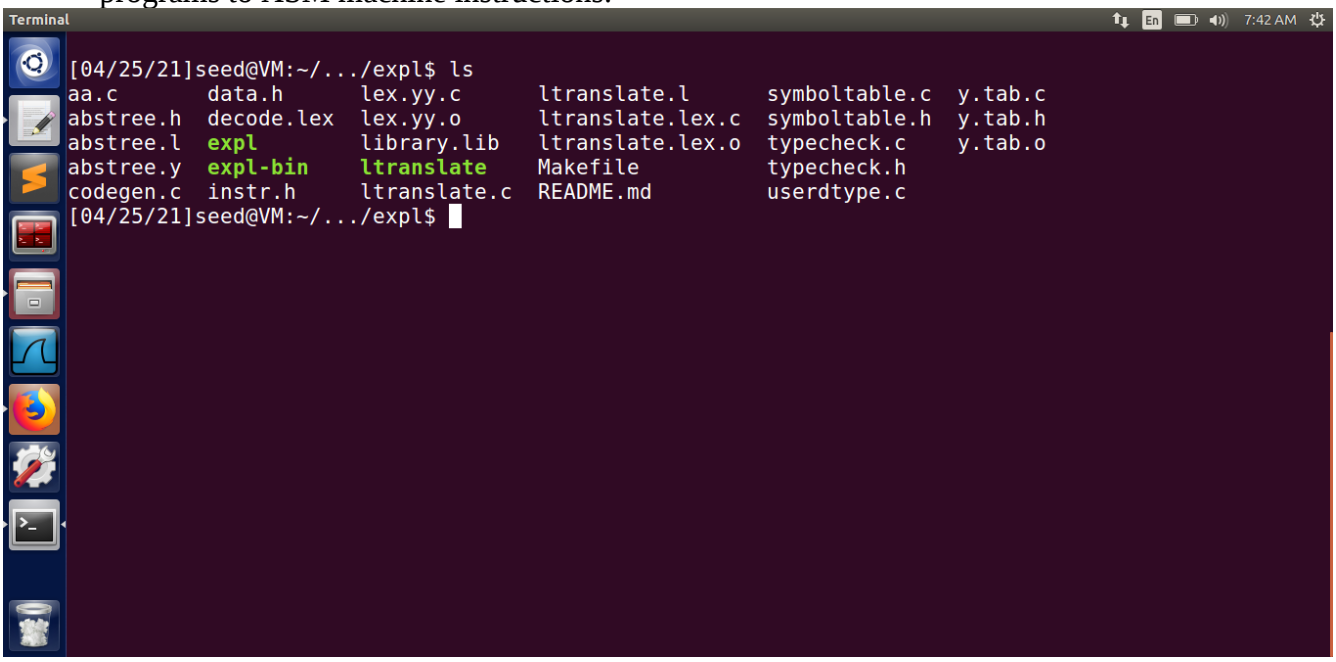
Code files are named in the below given format - fileName_stage_stageNumber.extension(.spl/.xsm)

This report contains screenshots and an explanation of the outputs of the assignment questions stage-vise.

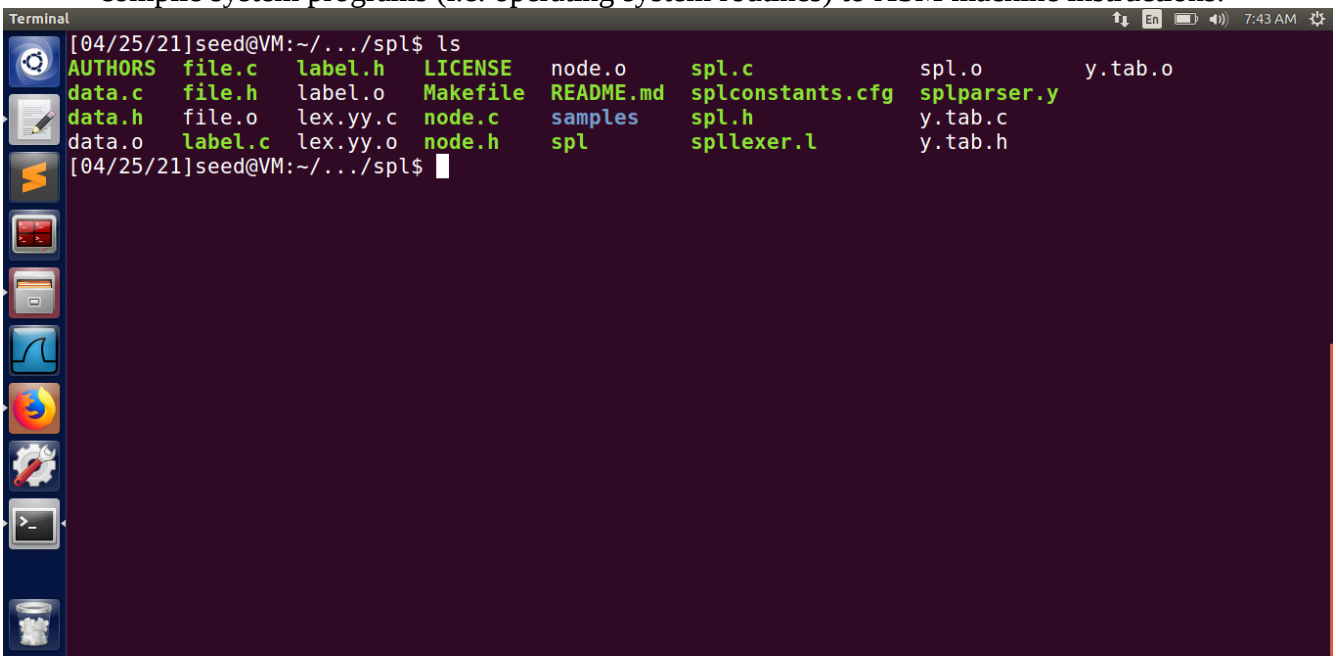
STAGE 1 : Set up the environment to build eXpOS

```
1. sudo apt-get install libreadline-dev flex bison make gcc wget curl
2. curl -sSf https://raw.githubusercontent.com/eXpOSNitc/expos-
bootstrap/main/download.sh | sh
3. cd $HOME/myexpos
4. make
```

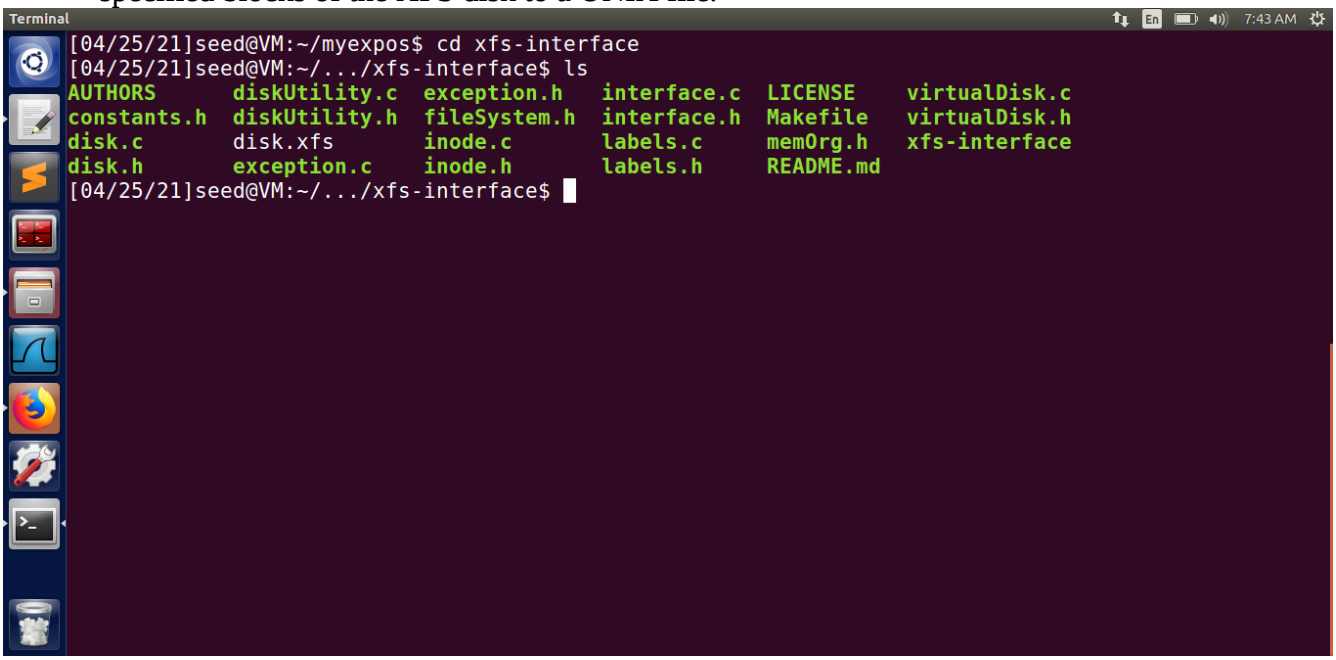
- This directory contains the Expl (Experimental Language) compiler required to compile user programs to XSM machine instructions.



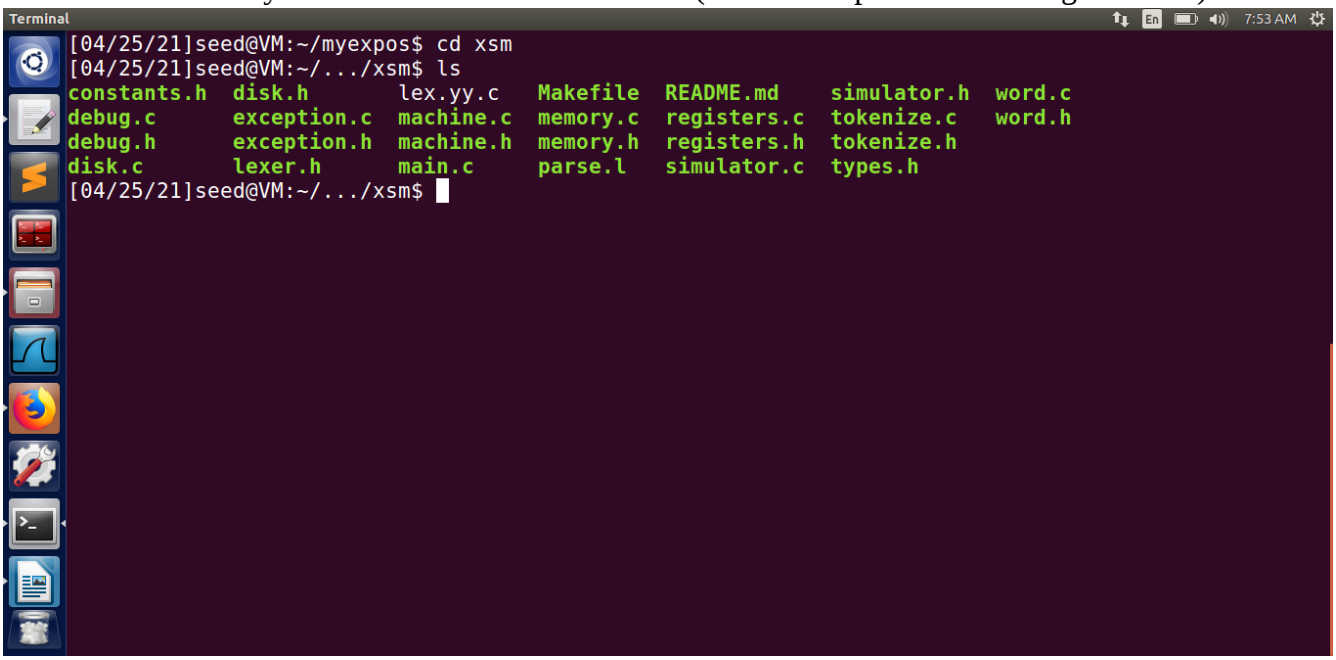
- This directory contains the SPL (System Programmer's Language) Compiler required to compile system programs (i.e. operating system routines) to XSM machine instructions.



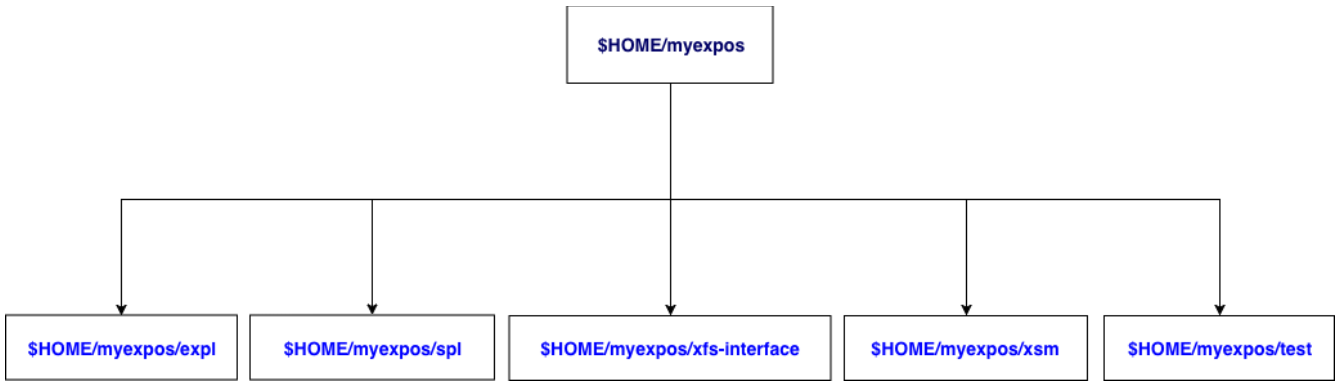
- This directory contains an interface (XFS Interface or eXperimental File System Interface) through which files from your UNIX machine can be loaded into the File System of XSM. The interface can format the disk, dump the disk data structures, load/remove files, list files, transfer data and executable files between eXpFS filesystem and the host (UNIX) file system and copy specified blocks of the XFS disk to a UNIX file.



- This directory contains the machine simulator (XSM or eXperimental String Machine).



We have done the setting of system correctly.
Below image shows the set of directories.

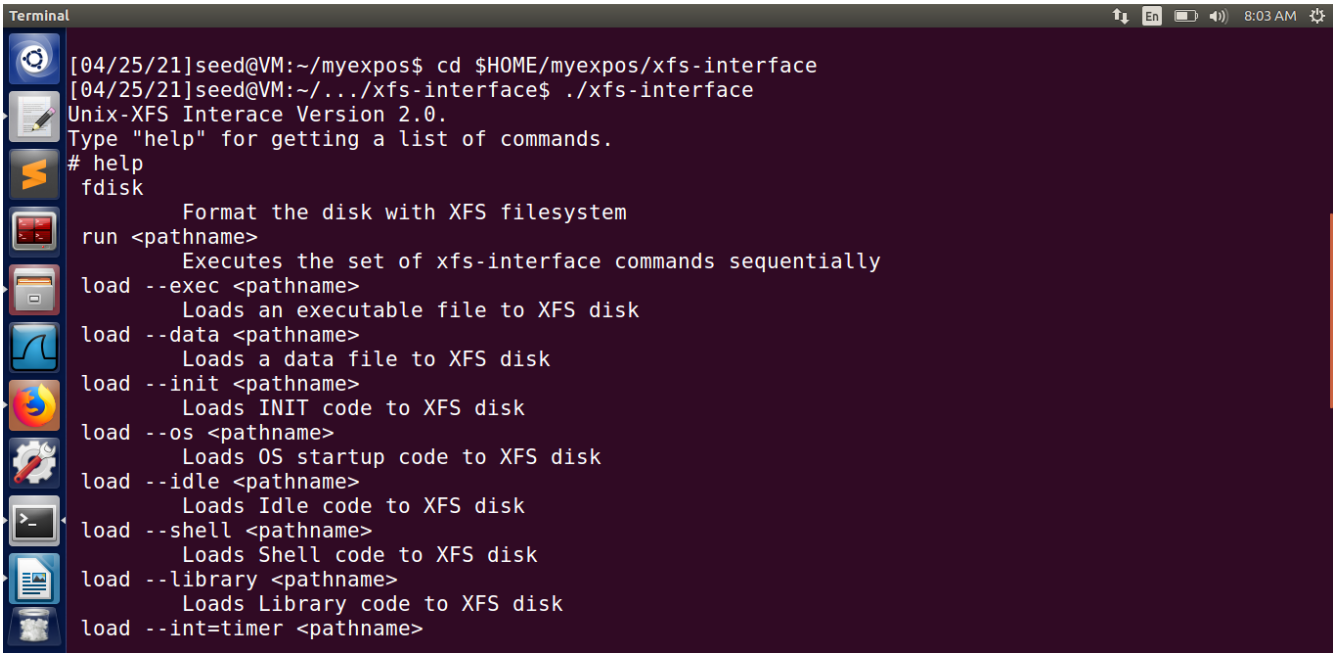

$HOME/myexpos
$HOME/myexpos/expl
$HOME/myexpos/spl
$HOME/myexpos/xfs-interface
$HOME/myexpos/xsm
$HOME/myexpos/test

Stage 2 : Understanding the Filesystem

The eXpOS package that we had downloaded in the previous stage consists mainly of a machine simulator. The machine is called the **eXperimental String Machine (XSM)** and consists of a processor, memory and disk. Some support tools that help us to program the machine are also provided.

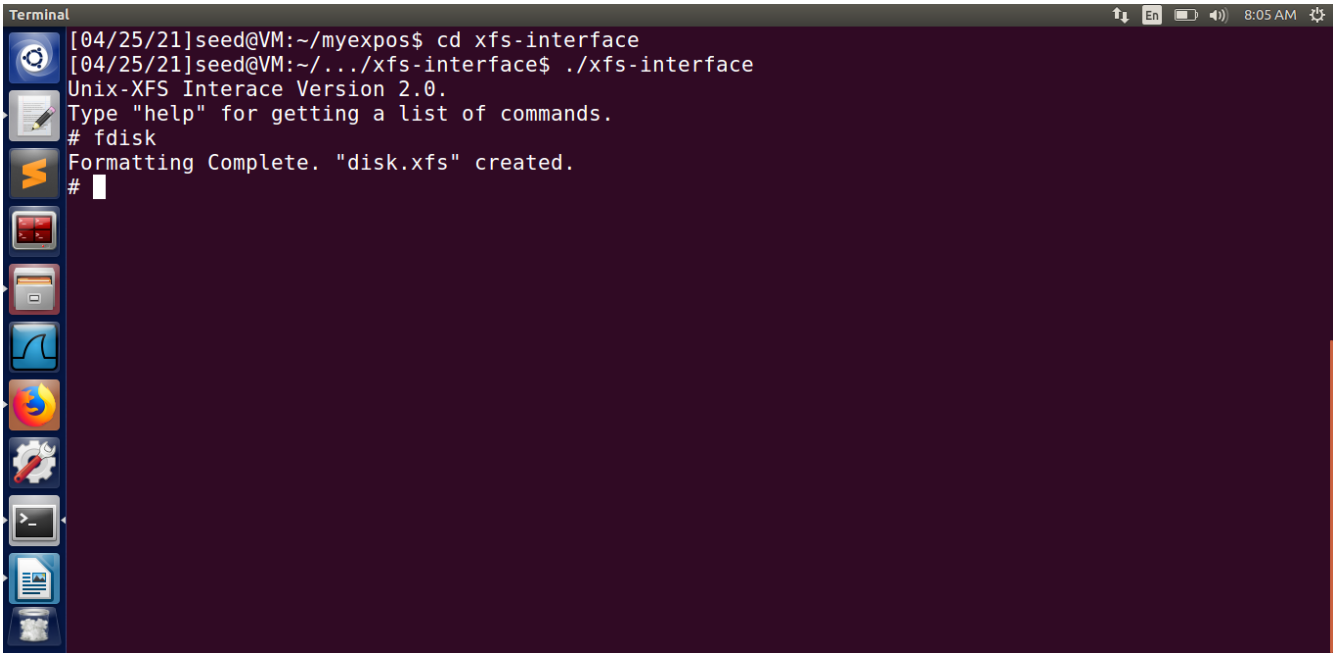
In this stage, we will create a text file and load it to the XFS disk using xfs-interface.

1. cd $HOME/myexpos/xfs-interface
`./xfs-interface`

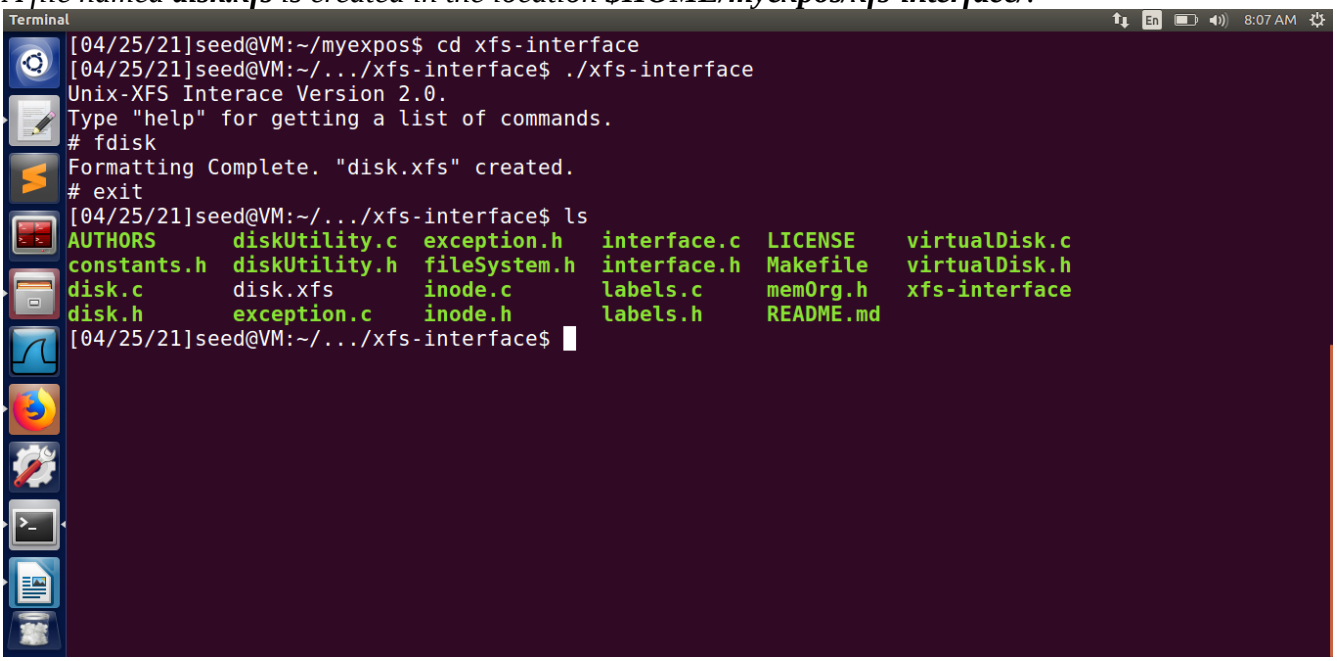


2. # fdisk
`# exit`

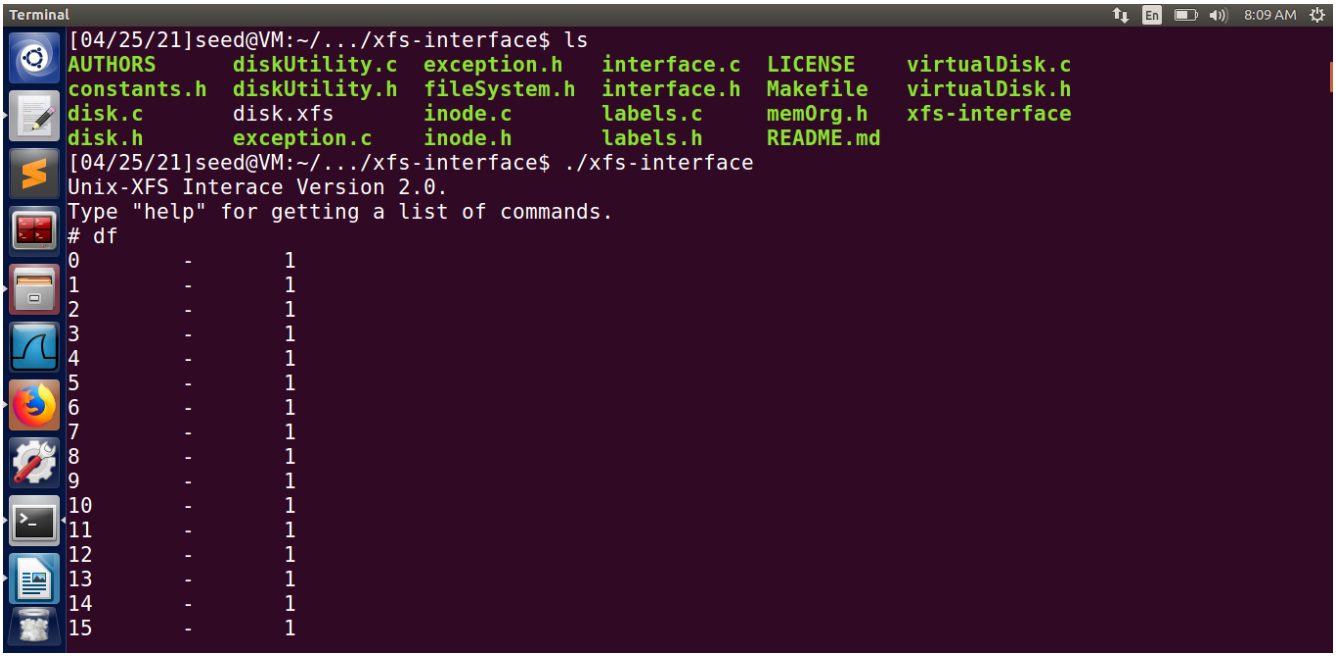
The fdisk command converts the raw disk into the filesystem format recognised by the eXpOS operating system.

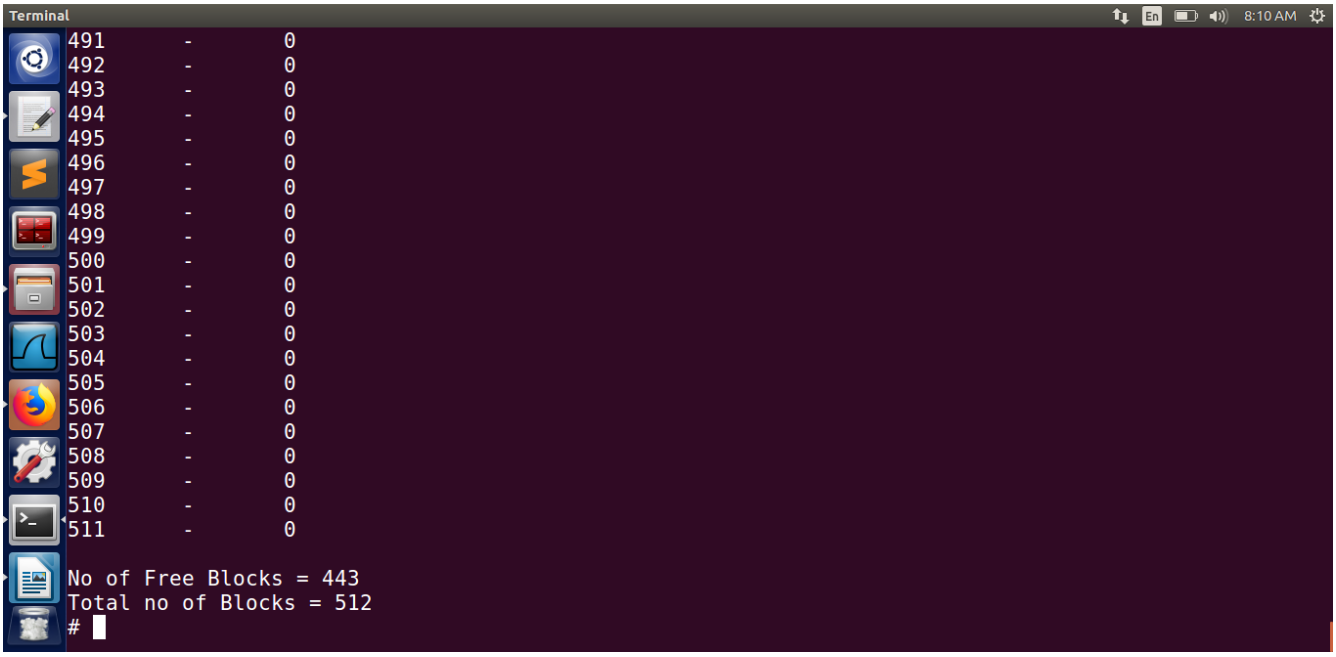


*A file named **disk.xfs** is created in the location **$HOME/myexpos/xfs-interface/**.*



3. The Disk Free List in XFS is a data structure which keeps track of used and unused blocks in the disk. An unused block is indicated by 0 and a used block is indicated by 1.

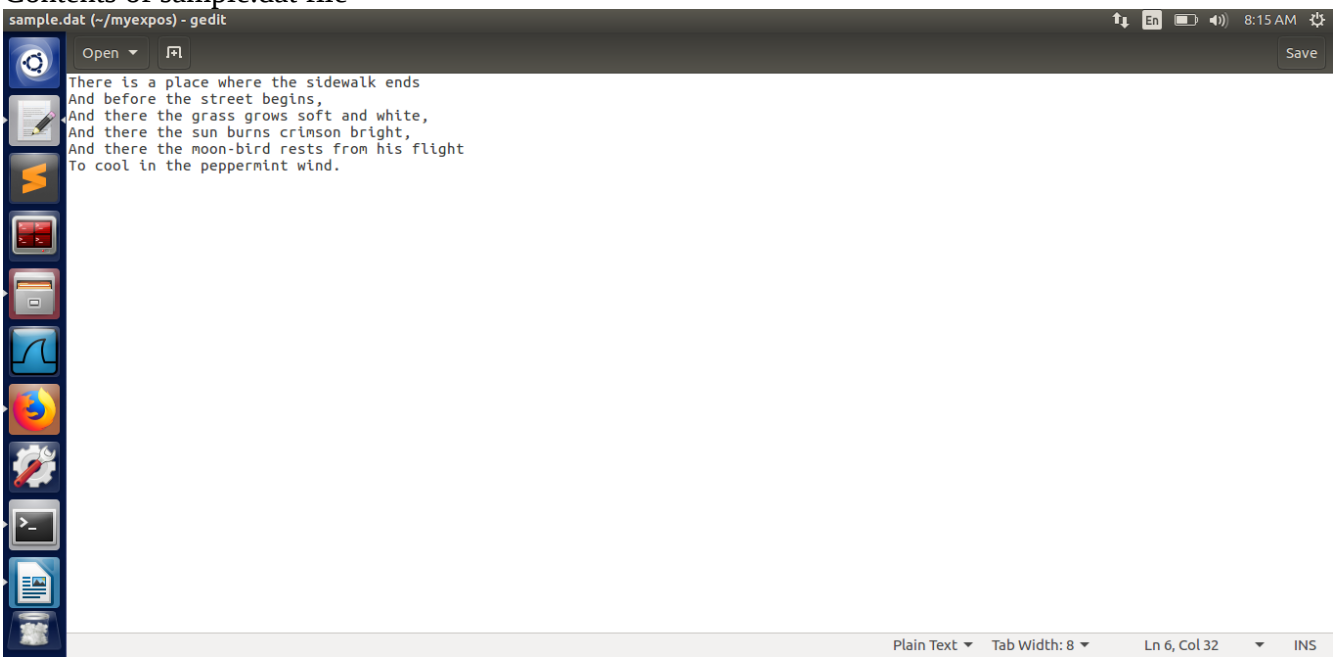




The first 69 blocks (blocks 0 to 68) are reserved for stroing various OS data structures and routines as well as Idle code, INIT program, etc. Hence the Disk Free List entries for these are marked as 1 (used) and the remaining entries for blocks 69 to 511 are 0.

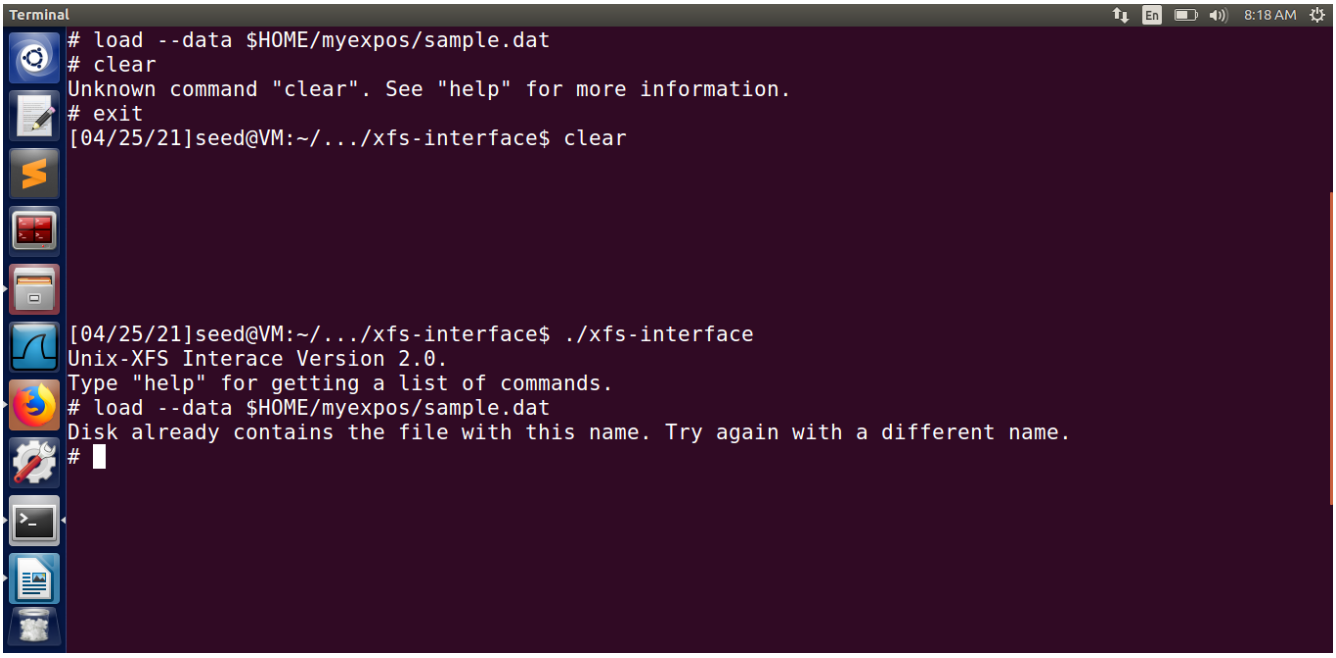
4. Created a sample.dat file.

Contents of sample.dat file -

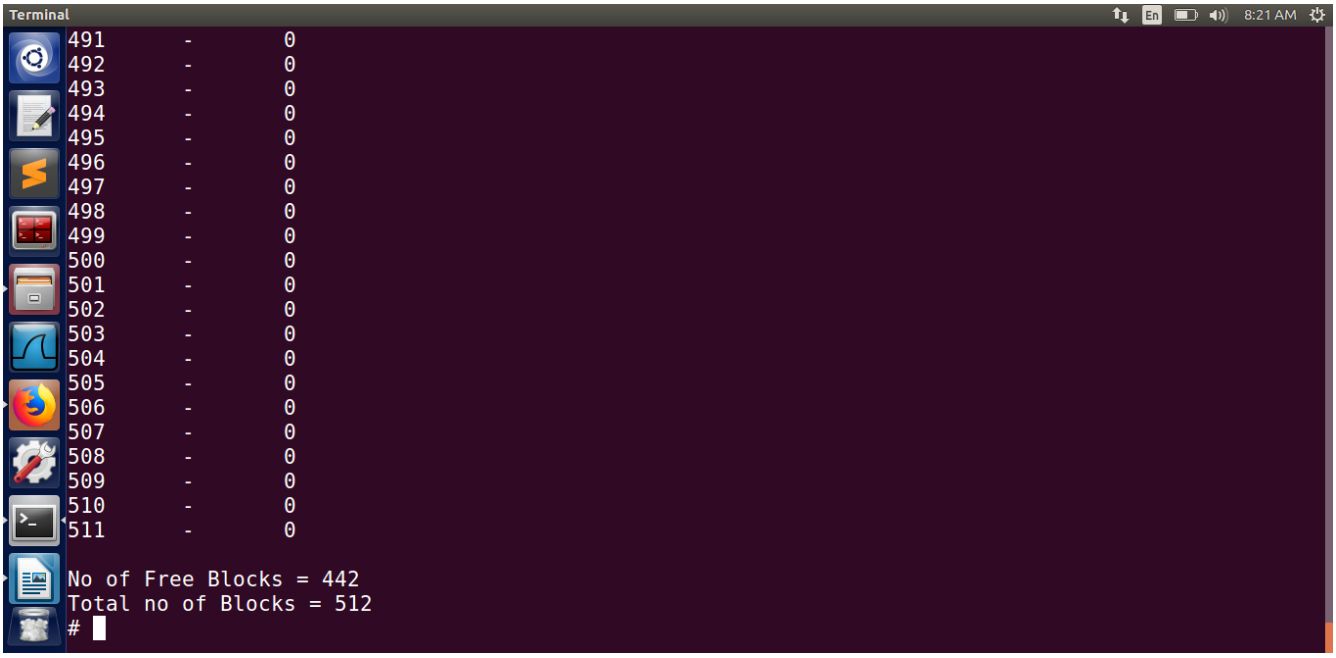


5. Loading this data file (`$HOME/myexpos/sample.dat`) to the XFS disk from your UNIX machine.

Command - # load --data $HOME/myexpos/sample.dat



- A disk block will be allocated for the file (as `sample.dat` contains less than 512 words) and corresponding to this allocated block (here block 69 - this is because the 1st free block is allocated by the allocator), an entry will be marked as 1 (used) in the Disk Free List.



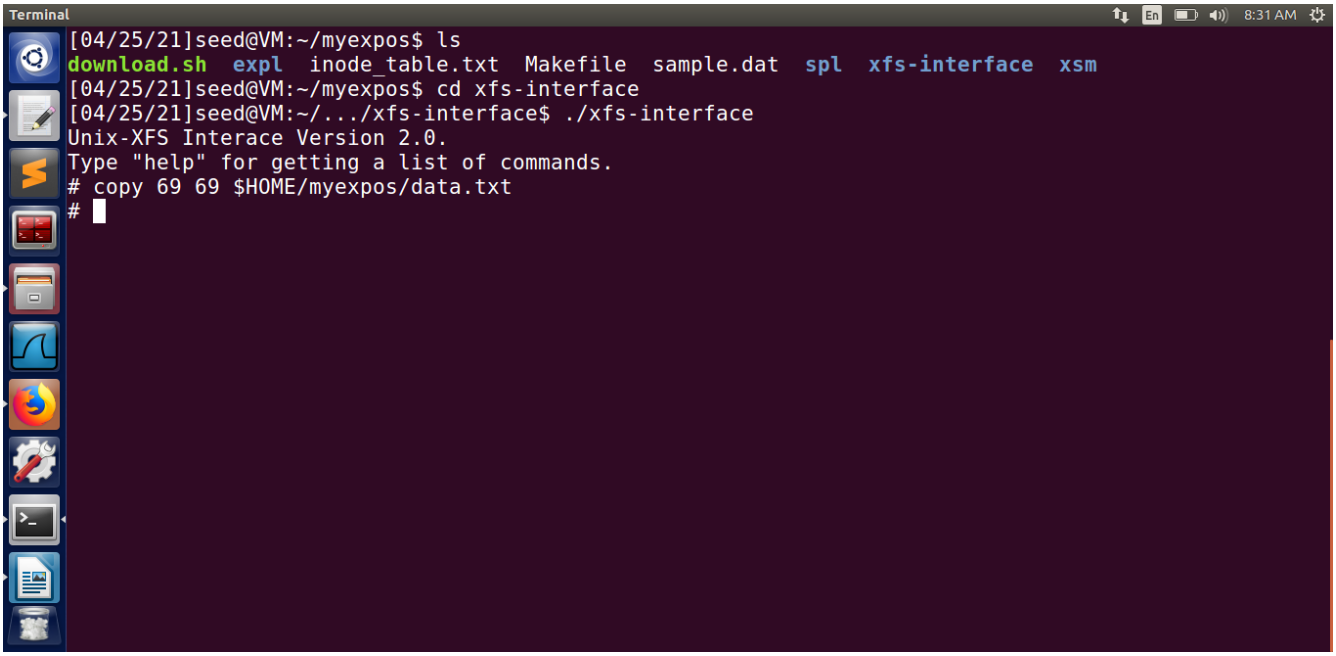
6. Use the **copy** command to copy the *Inode Table*(Inode Table is stored in disk blocks 3 and 4) to a UNIX file (say `$HOME/myexpos/inode_table.txt`).

```
Command - # copy 3 4 $HOME/myexpos/inode_table.txt
```

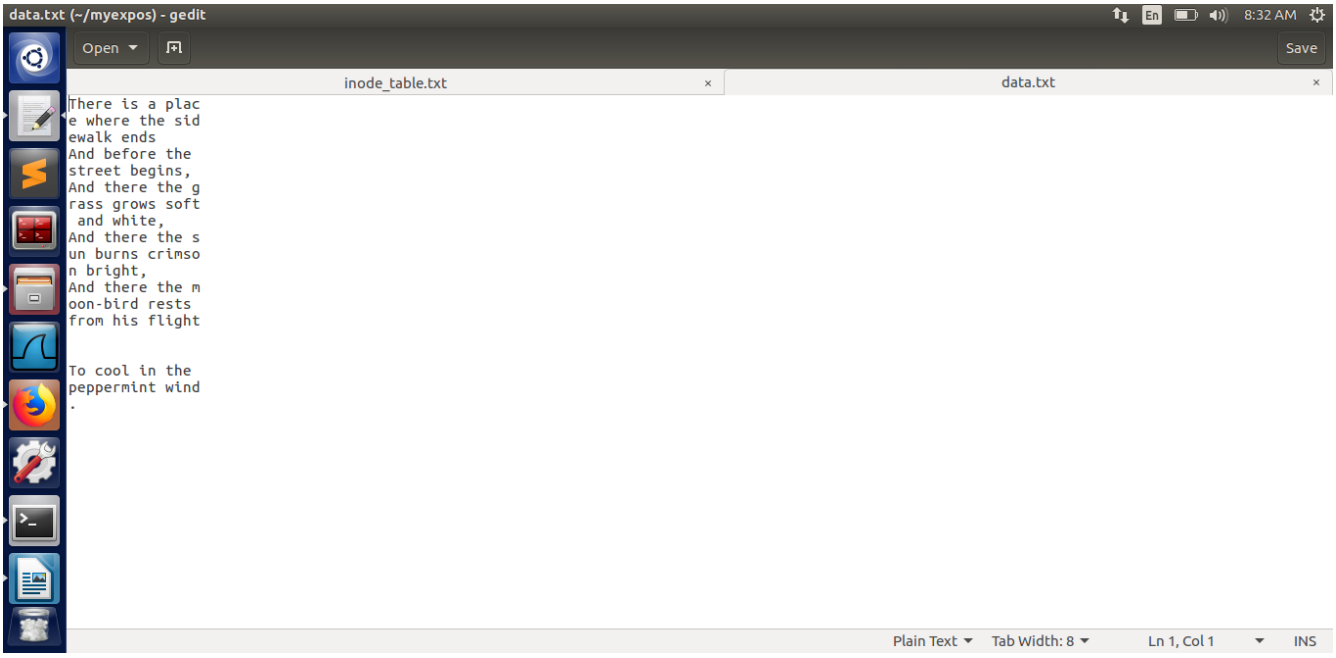

```
Contents of inode_table.txt.
```

7. Copy the data blocks from the XFS disk and display it as a UNIX file.

Command - # copy 69 69 $HOME/myexpos/data.txt

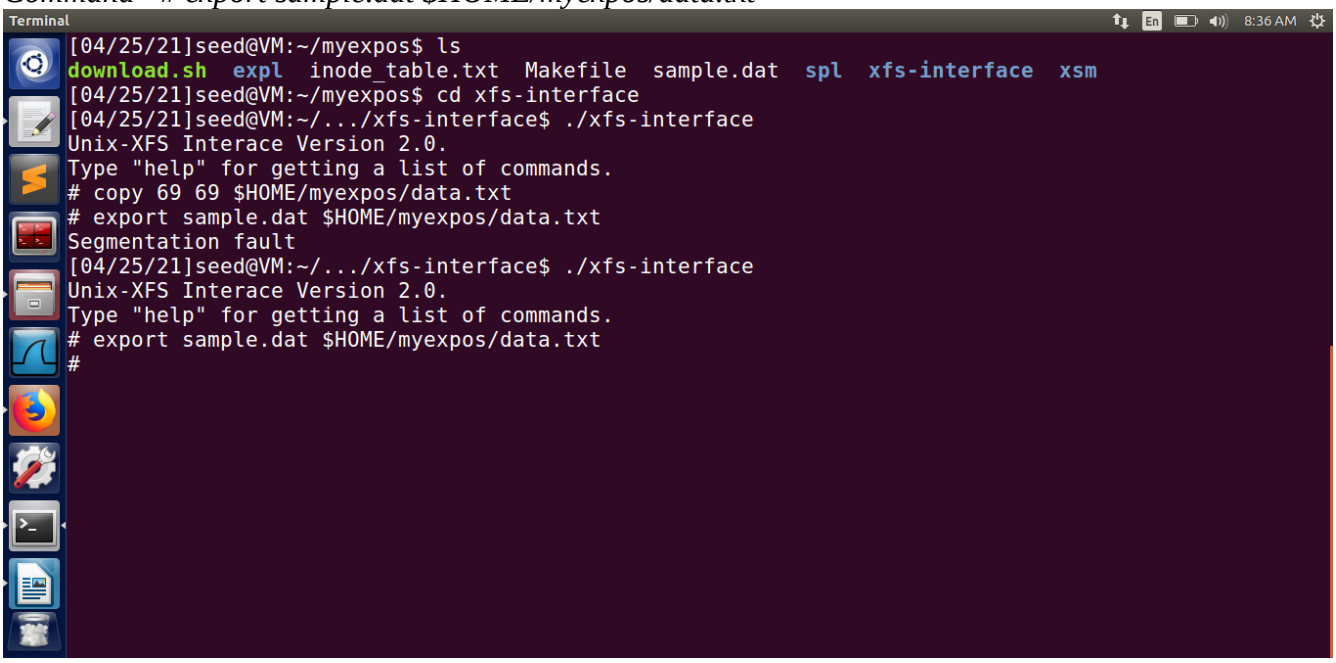


Each word is displayed in a line because a word in XFS is 16 characters long. Sample `data.txt` file is shown below.



8. Export the file `sample.dat` to the UNIX file `$HOME/myexpos/data.txt` using *xfs-inteface*

Command - # export sample.dat $HOME/myexpos/data.txt



Question 1: When a file is created entries are made in the Inode table as well as the Root file. What is the need for this duplication?

Answer - The Inode table is stored in the disk and has an entry for each file present in the disk. The eXpoS reserves the first entry in the Inode table for the root file. The root file is a special file containing details about other files stored in the system.

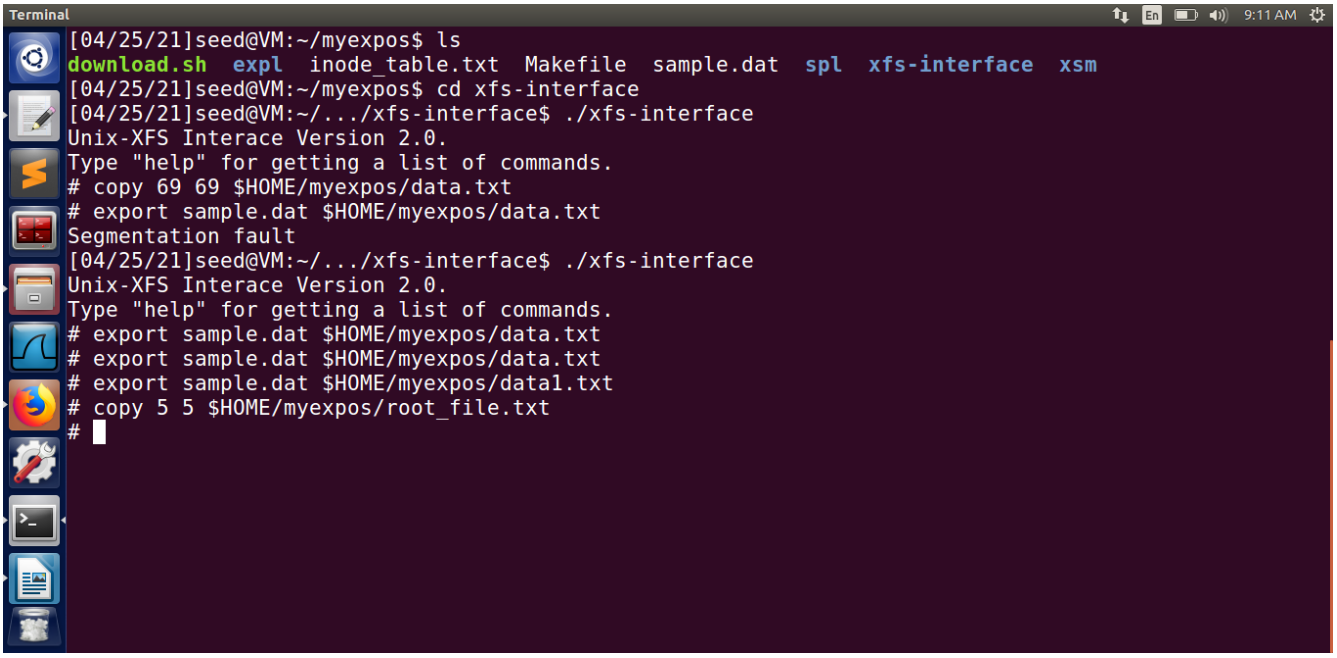
The reason for this duplication is that root file is designed to be readable by user programs using the *Read* system call (unlike the inode table, which is accessed exclusively by OS routines only). An application readable root file allows implementation of commands like “ls” as user mode programs. *Write* and *Delete* system calls are not permitted on the root file.

The only data in the root file entry of a file that is not present in the inode table is the user name of the owner of the file. The inode table entry of a file contains a user-id of the owner. The user-id value can be used to index into the user table to find the username corresponding to the user-id.

Assignment 1: Copy the contents of Root File (from Block 5 of XFS disk) to a UNIX file `$HOME/myexpos/root_file.txt` and verify that an entry for `sample.dat` is made in it also.

Answer -
Command - copy 5 5 $HOME/myexpos/root_file.txt

Contents of root_file.txt are shown.
Entry of sample.dat is made in the Root File.



Assignment 2: Delete the `sample.dat` from the XSM machine using xfs-interface and note the changes for the entries for this file in *inode table, root file and disk free list* .

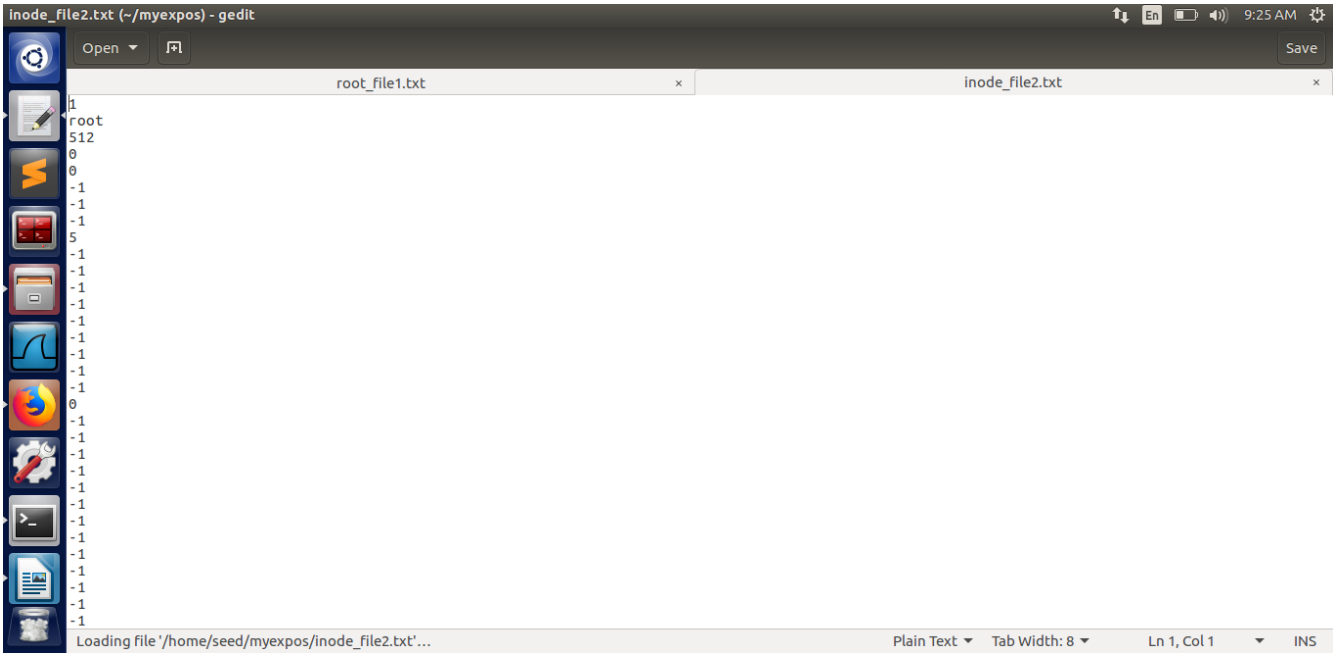
Answer -

Command - # rm sample.dat

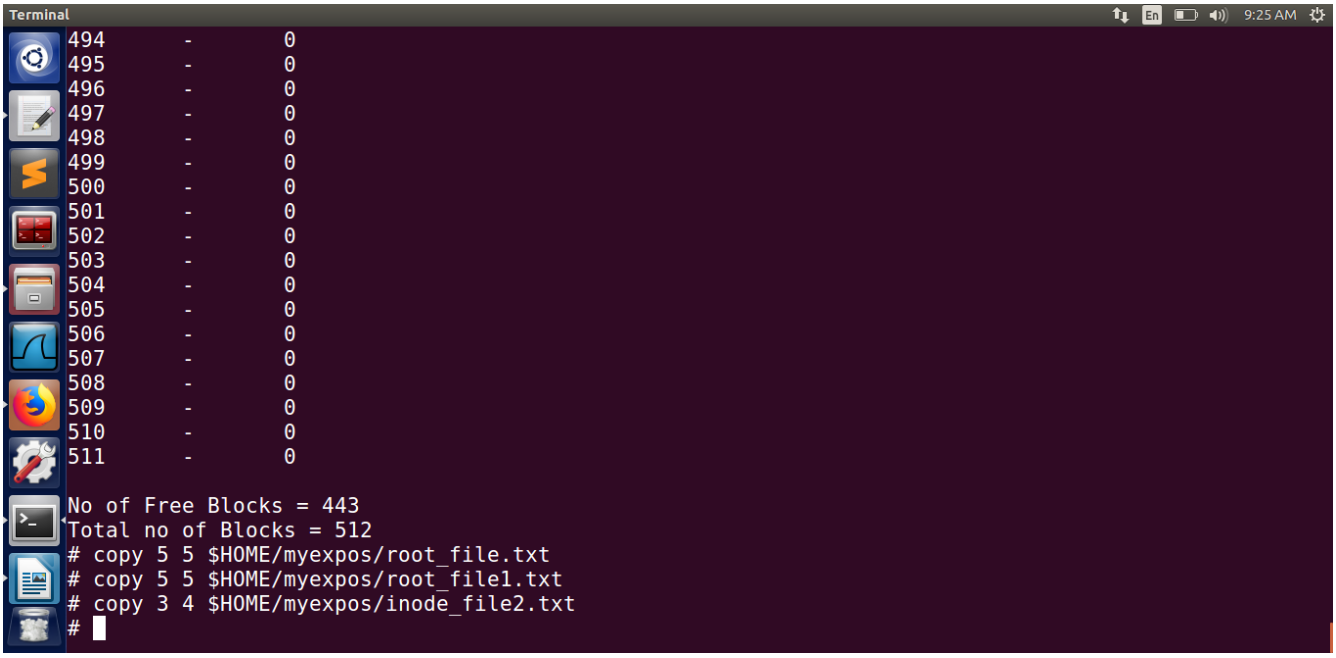
Disk Free List - 69th entry is 0

Root file – No entry for sample.dat file.

Inode table – No entry for sample.dat.



Commands used -


Terminal
9:25 AM
494 - 0
495 - 0
496 - 0
497 - 0
498 - 0
499 - 0
500 - 0
501 - 0
502 - 0
503 - 0
504 - 0
505 - 0
506 - 0
507 - 0
508 - 0
509 - 0
510 - 0
511 - 0
No of Free Blocks = 443
Total no of Blocks = 512
copy 5 5 $HOME/myexpos/root_file.txt
copy 5 5 $HOME/myexpos/root_file1.txt
copy 3 4 $HOME/myexpos/inode_file2.txt
#

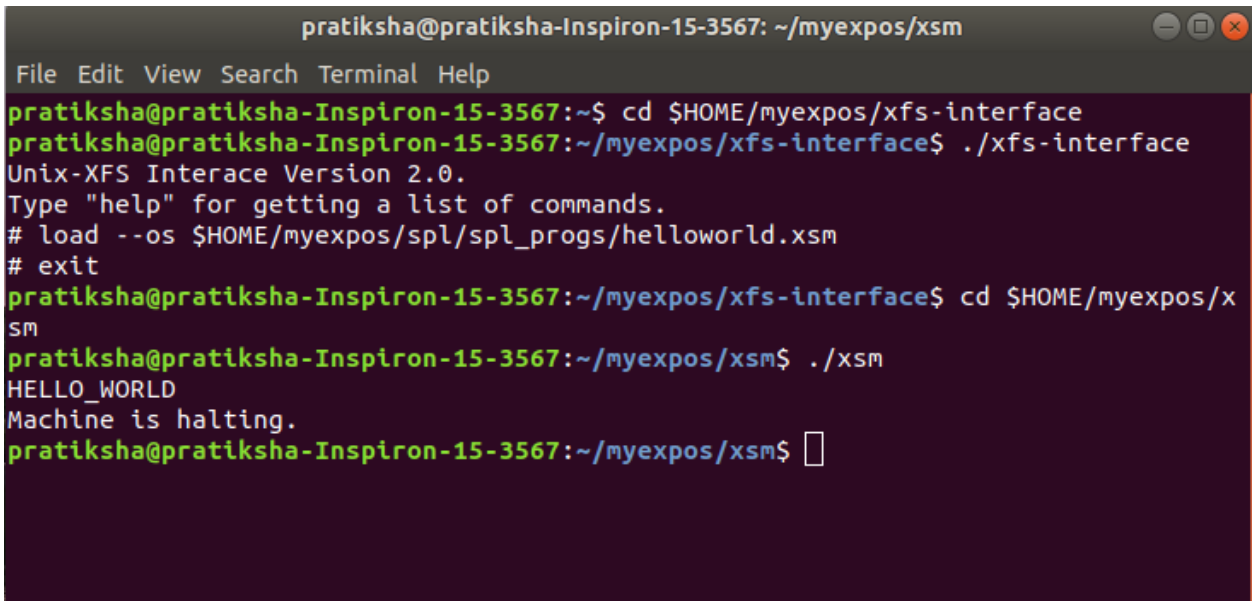
Stage 3

BOOTSTRAP LOADER
Whenever the machine starts, the execution of the program starts at the first word of the first page(page 0) of the memory. There is a pre-loaded ROM code on Page 0 called the **bootstrap loader**. This code loads the 1st disk block (block 0) called the **boot block** from the disk to page 1 of memory and then transferred control (using the jump instruction) to the 1st instruction on page 1.
Boot ROM code contains only two instructions, the first instruction is to load the boot block to page 1 and the second instruction is to jump to page 1.

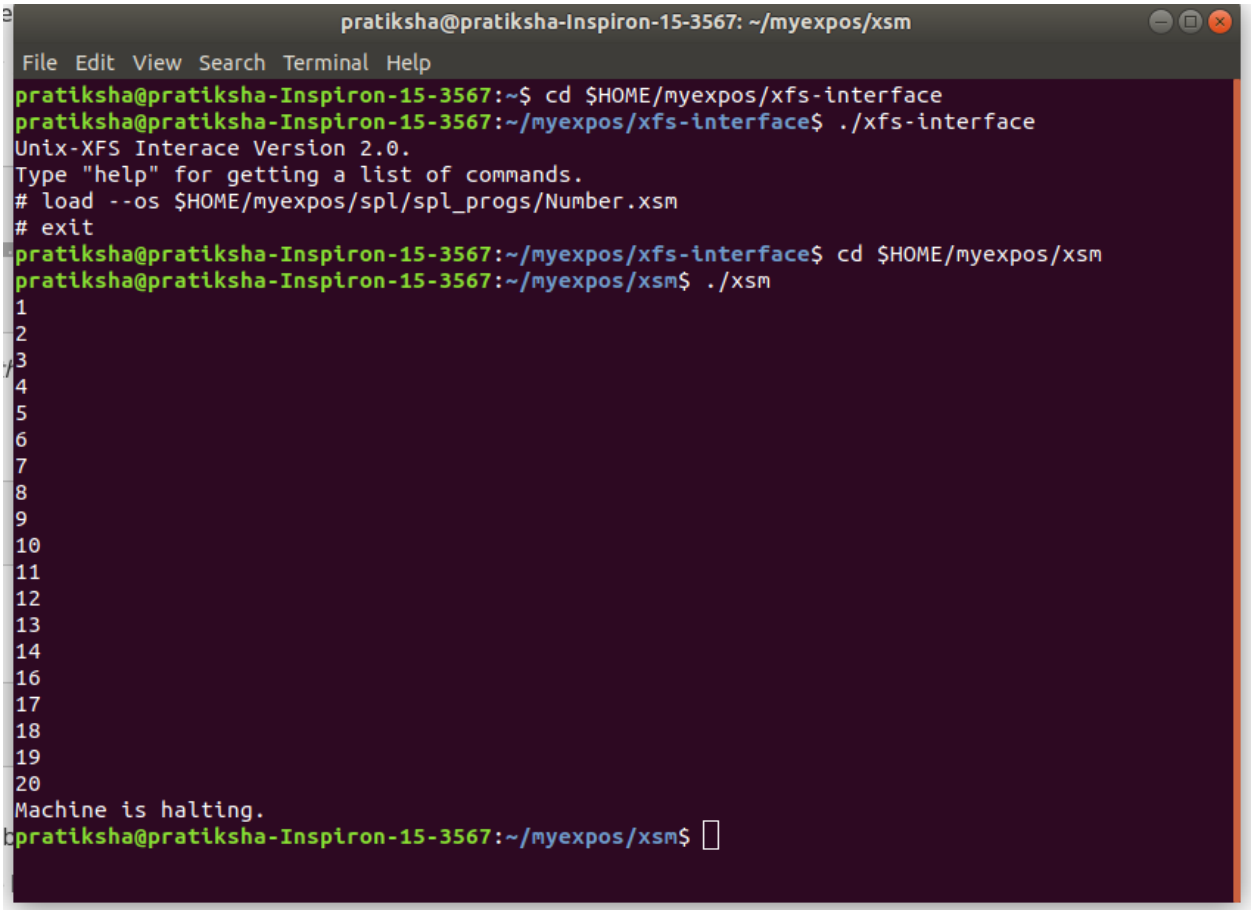
Assembly code to print “HELLO WORLD”:-

```
MOV R0, "HELLO_WORLD"
MOV R16, R0
PORT P1, R16
OUT
HALT
```

Load the file as OS Startup code to disk.xfs using XFS-Interface. Invoke the XFS interface
After that running the machine and here we go, it is printing “HELLO_WORLD”:



Assignment: Write an assembly program to print numbers from 1 to 20 and run it as the OS Startup code.
Link to the code:-
https://drive.google.com/file/d/1E8Vp2FJ4_0nA12eOudSfejgHHfo5kkHU/view?usp=sharing
The output:-


pratiksha@pratiksha-Inspiron-15-3567: ~/myexpos/xsm
File Edit View Search Terminal Help
pratiksha@pratiksha-Inspiron-15-3567:~$ cd $HOME/myexpos/xfs-interface
pratiksha@pratiksha-Inspiron-15-3567:~/myexpos/xfs-interface$ ./xfs-interface
Unix-XFS Interace Version 2.0.
Type "help" for getting a list of commands.
load --os $HOME/myexpos/spl/spl_progs/Number.xsm
exit
pratiksha@pratiksha-Inspiron-15-3567:~/myexpos/xfs-interface$ cd $HOME/myexpos/xsm
pratiksha@pratiksha-Inspiron-15-3567:~/myexpos/xsm$ ./xsm
1
2
3
4
5
6
7
8
9
10
11
12
13
14
16
17
18
19
20
Machine is halting.
pratiksha@pratiksha-Inspiron-15-3567:~/myexpos/xsm$

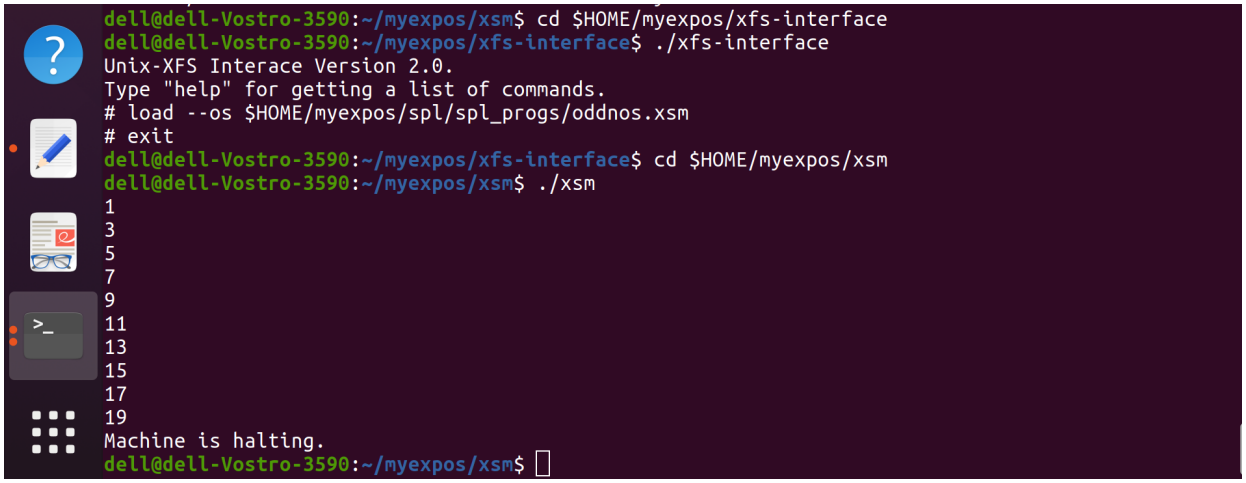
Stage 4

SPL (Systems Programming Language) allows high-level programs to be written for the XSM machine (eliminating the need to write all the code in assembly language). SPL is not a full-fledged programming language but is an extension to the XSM assembly language with support for high-level constructs like if-then-else, while-do, etc.

SPL doesn't support variables. Instead, you can directly use XSM registers for storing program data

SPL Program to print odd numbers from 1 to 20 :

```
alias counter R0;
counter = 0;
while(counter <= 20) do
  if(counter%2 != 0) then
    print counter;
  endif;
  counter = counter + 1;
endwhile;
```



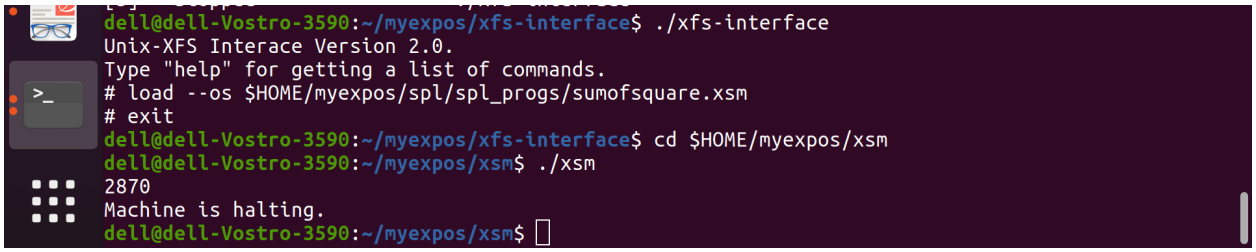
Assignment Question 1: Write the SPL program to print the sum of squares of the first 20 natural numbers. Load it using xfs interface and run the in the machine.

Code

```
alias counter R0;
alias sum R1;
alias temp R2;
```

```
counter = 0;
sum = 0;
temp = 0;

while(counter <= 20) do
  temp = counter * counter;
  sum = sum + temp;
  counter = counter + 1;
endwhile;
print sum;
```

Output:



Stage 5: XSM Debugging

In this stage, I have written an SPL program with a **breakpoint** statement.

The breakpoint statement translates to the BEKP machine instruction and is used for debugging. Suppose the XSM machine is run in the Debug mode on encountering the BRKP instruction. In that case, the machine simulator will suspend the program execution and allow you to inspect the values of the registers, memory, os data structures, etc. Execution resumes only after you instruct the simulator to proceed.

1. SPL code to generate odd numbers from 1 to 10.

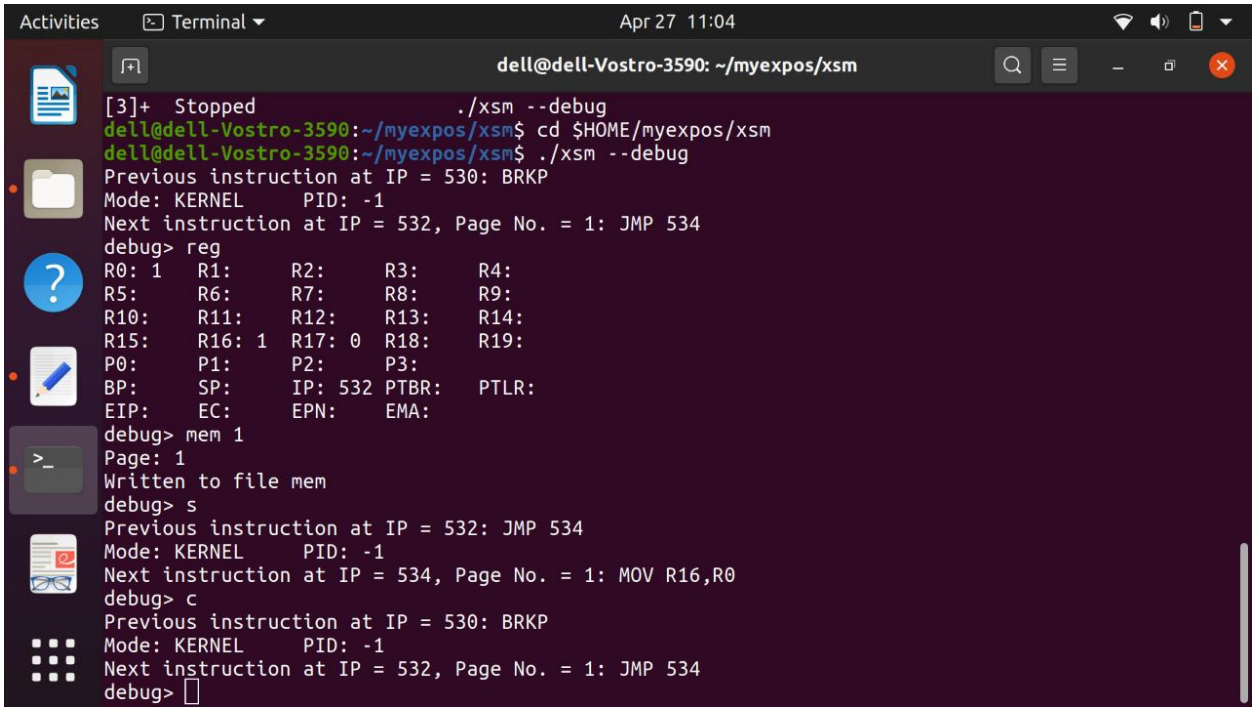
```
alias counter R0;
counter = 0;
while(counter <= 10) do
  if(counter%2 != 0) then
    breakpoint;
  endif;
  counter = counter + 1;
endwhile;
```

2. I compiled the program using the SPL compiler.
3. Loaded the compiled xsm code as OS startup code into the XSM disk using the XFS interface.
4. Run the machine in debug mode.

```
cd $HOME/myexpos/xsm
./xsm --debug
```

5. The Machine pauses after the execution of the first BRKP instruction.

Output -


Activities
Terminal
Apr 27 11:04
dell@dell-Vostro-3590: ~/myexpos/xsm
[3]+ Stopped ./xsm --debug
dell@dell-Vostro-3590:~/myexpos/xsm$ cd $HOME/myexpos/xsm
dell@dell-Vostro-3590:~/myexpos/xsm$ ./xsm --debug
Previous instruction at IP = 530: BRKP
Mode: KERNEL PID: -1
Next instruction at IP = 532, Page No. = 1: JMP 534
debug> reg
R0: 1 R1: R2: R3: R4:
R5: R6: R7: R8: R9:
R10: R11: R12: R13: R14:
R15: R16: 1 R17: 0 R18: R19:
P0: P1: P2: P3:
BP: SP: IP: 532 PTBR: PTLR:
EIP: EC: EPN: EMA:
debug> mem 1
Page: 1
Written to file mem
debug> s
Previous instruction at IP = 532: JMP 534
Mode: KERNEL PID: -1
Next instruction at IP = 534, Page No. = 1: MOV R16,R0
debug> c
Previous instruction at IP = 530: BRKP
Mode: KERNEL PID: -1
Next instruction at IP = 532, Page No. = 1: JMP 534
debug>

Stage 6: Running a user program

In this stage, we will be running our first user program, squares.xsm.

File - expl_progs/squares.xsm

This is the user program that we want to run, which calculates the square of the first 5 natural numbers. This code will be loaded as an INIT program by the OS startup code.

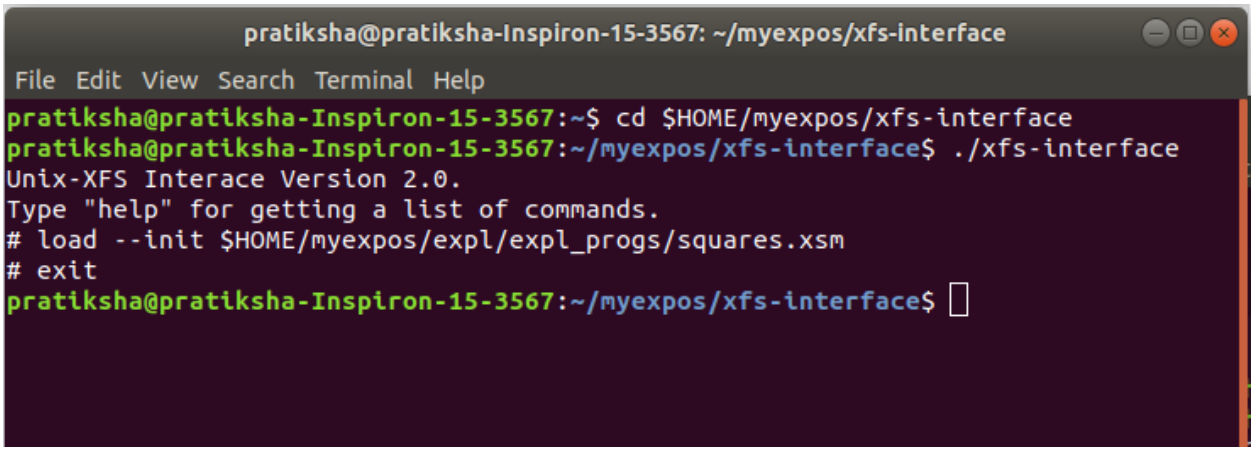
File- spl_progs/haltprog.spl

This spl program has only a halt statement and will be used as interrupt handler 10 and also the exception handler. At the end of the user program, an INT 10 instruction is used to give control back to os and invoke the software interrupt handler 10. Its default action is to halt the machine.

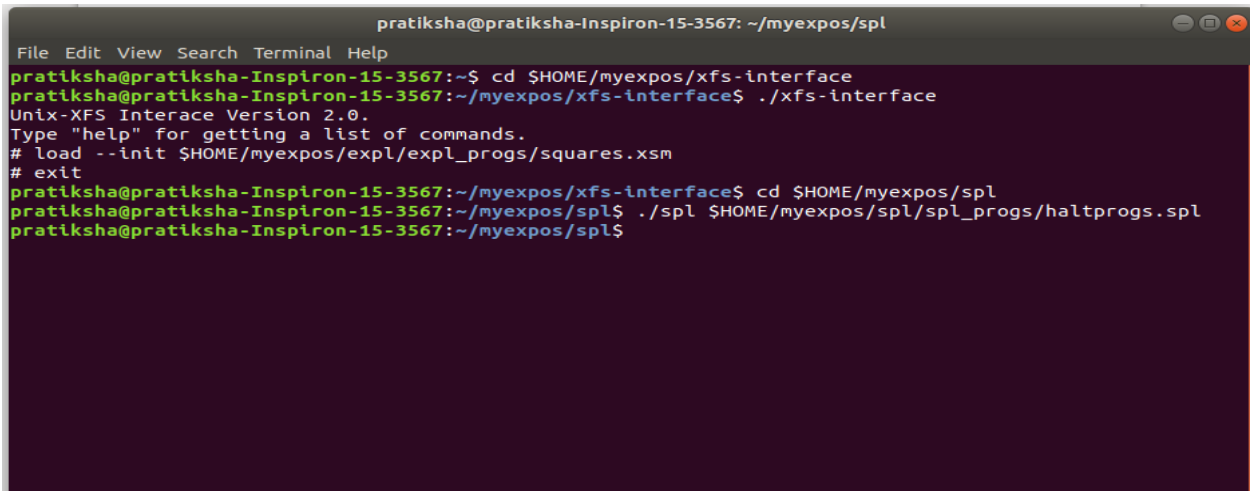
File- spl_progs/os_startup.spl

This is the os startup code that loads the rest of the program from the disk to memory. It sets up the page table for the INIT program, sets the value for PTBR and PTLR registers, and also sets the stack. Once everything is set, the code transfers the control to the INIT program using IRET instruction.

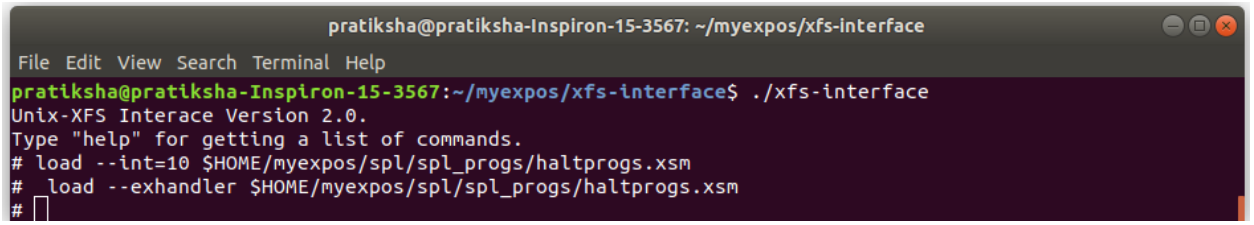
Loading the file squares.xsm to the xsm disk as the INIT program using the XFS interface.



Compiling the haltprogs.spl after creating it.



Loading the compiling code as INT 10 from xfs-interface.

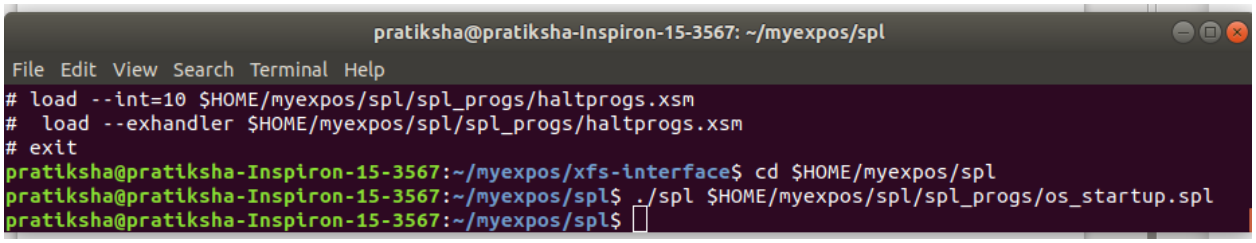


OS startup code:

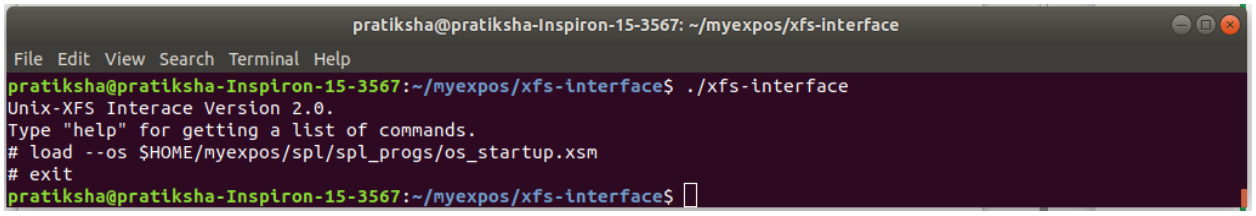
```
loadi(65,7);
loadi(66,8);
loadi(22,35);
loadi(23,36);
loadi(2, 15);
loadi(3, 16);
PTBR = PAGE_TABLE_BASE;
PTLR = 3;
[PTBR+0] = 65;
[PTBR+1] = "0100";
[PTBR+2] = 66;
[PTBR+3] = "0100";
[PTBR+4] = 76;
```

```
[PTBR+5] = "0110";
[76*512] = 0;
SP = 2*512;
ireturn;
```

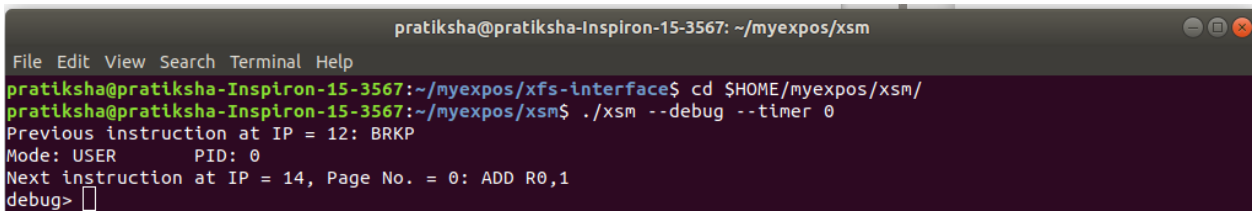
Saving the OS startup code as $HOME/myexpos/spl/spl_progs/os_startup.spl. Compiler this file using SPL compiler.



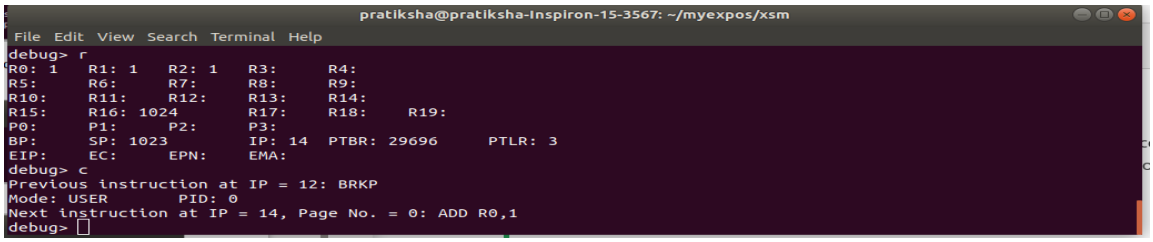
This generates a file $HOME/myexpos/spl/spl_progs/os_startup.xsm. Load this file as os startup code to disk.xfs using xfs interface.

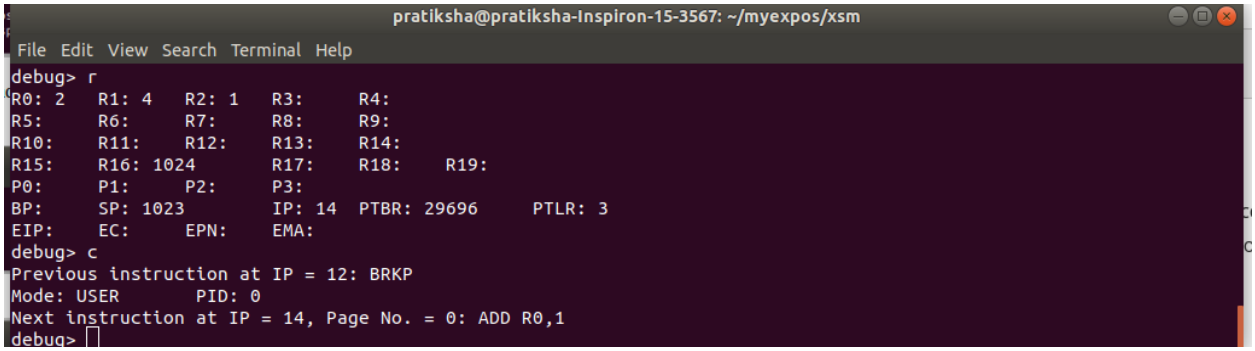


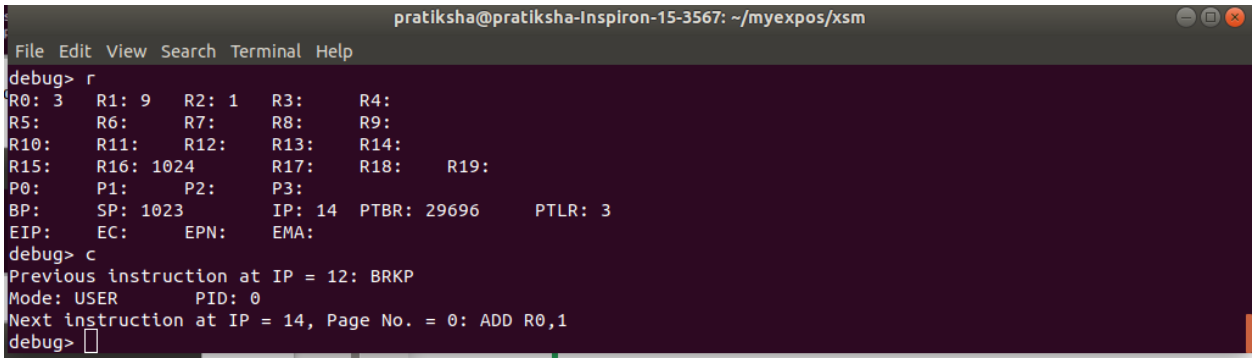
Running the machine in debug mode:

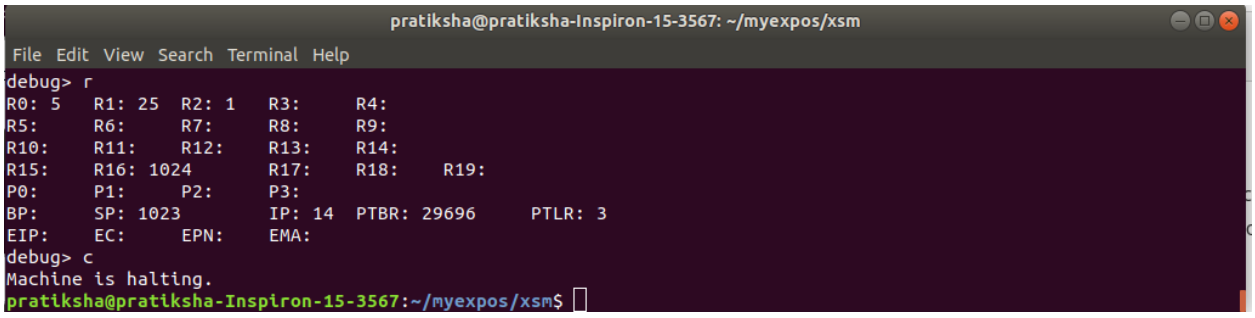


Viewing R1 in each iteration:-









Its explanation:-

The files are loaded into the following disk blocks:-

Block no.	Contents
0-1	bootstrap/OS start code
...	...
7-8	init/login code
...	...
15-16	Exception Handler
...	...
35-36	interrupt 10 Routine:Exit
...	...

The ROM code (present on page 0) on the machine loads the OS startup code from disk block 0 to memory page 1 and sets P to 512, which is the first instruction on page 1. memory layout:-

Physical page number	contents
0	Rom code
1	Page for OS start up code
2-3	expection handler
...	...
22-23	Interrupt 10 Routine: Exit
...	...
58	Page Tables*
...	...
65-66	Init/Login code
...	...

The OS startup program loads the disk blocks to their corresponding page numbers.

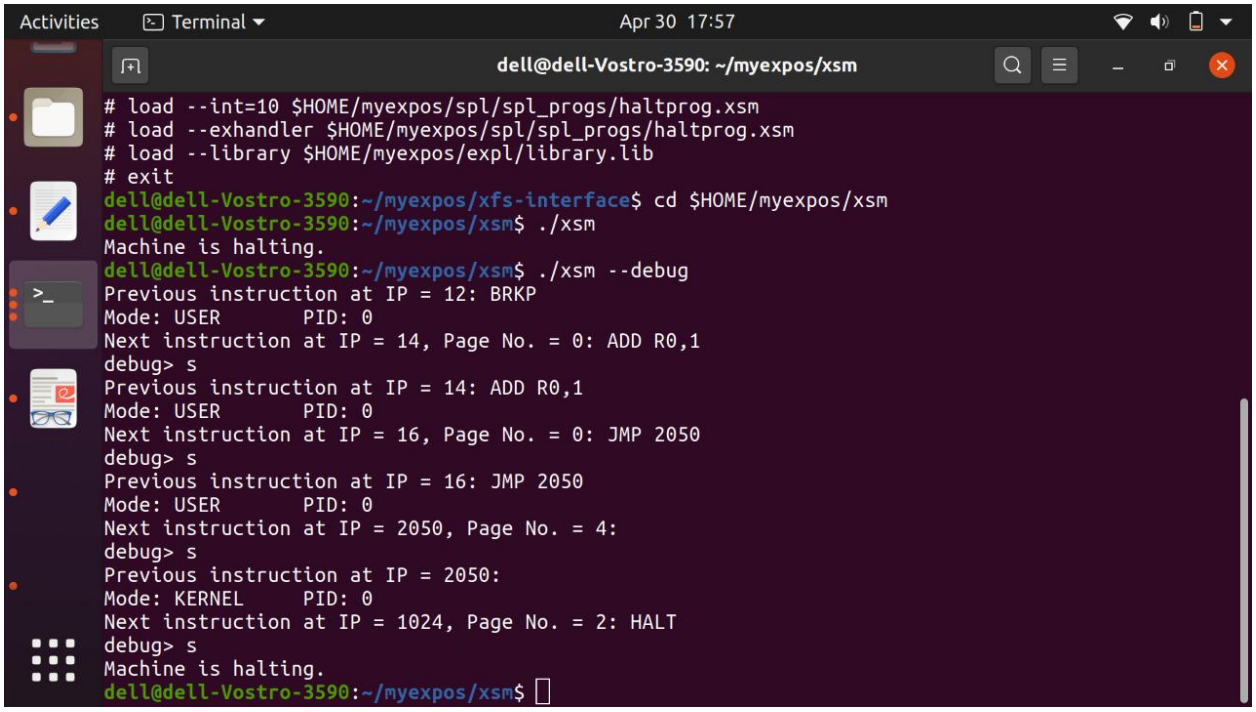
Page table for INIT program

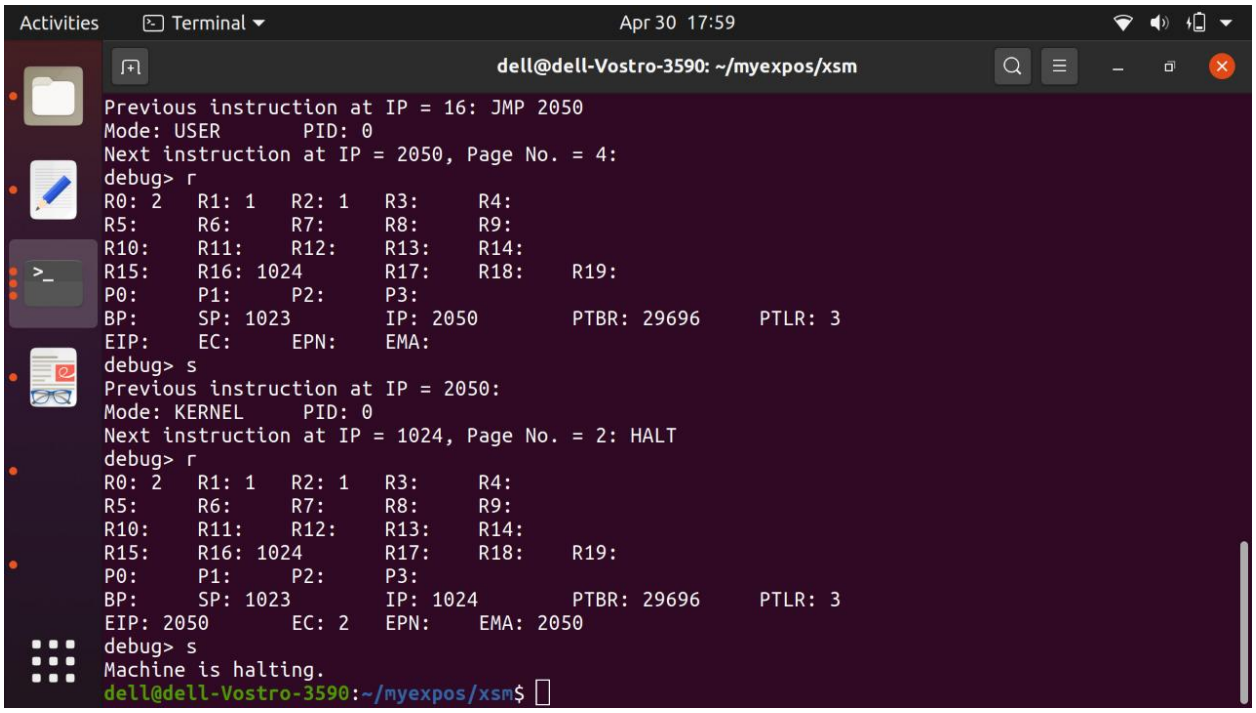
Each page table entry for a logical page is of 2 words. The first word is the physical page number and the second word contains a series of flags such as reference bit, valid/invalid bit, write permission bit, and dirty bit.

Memory address	Physical page number	flags
PTBR	65	0100
PTBR+2	66	0100
PTBR+4	76	0110

Assignment: Change virtual memory model such that code occupies logical pages 4 and 5 and the stack lies in logical page 8. You will have to modify the user program as well as the os startup code.

Output -





Stage 7: (ABI and XEXE Format)
An application binary interface (ABI) is the interface between a user program and the kernel.

In this stage, we will rewrite the user program and OS startup code of Stage 6 in compliance with expos ABI.

The INIT program must be modified to comply with the XEXE executable format.

Modified init program code

```
0
2056
0
0
0
0
0
0
MOV R0, 1
MOV R2, 5
GE R2, R0
JZ R2, 2074
MOV R1, R0
MUL R1, R0
BRKP
ADD R0, 1
JMP 2058
INT 10
```

Modified OS startup program code

```
//Loads library code from disk blocks 13 and 14 to physical pages 63 and 64
loadi(63,13);
loadi(64,14);

//Loads INIT program from 7, 8 blocks to 65, 66 physical  pages
loadi(65,7);
loadi(66,8);
```

```
//Loads interrupt routine 10 from 35, 36 blocks to 22, 23 physical pages
loadi(22,35);
loadi(23,36);

//Loads exception handler from 15, 16 blocks to 2, 3 physical pages
loadi(2, 15);
loadi(3, 16);
PTBR = PAGE_TABLE_BASE;
PTLR = 10;

//Library
[PTBR+0] = 63;
[PTBR+1] = "0100";
[PTBR+2] = 64;
[PTBR+3] = "0100";

//Heap
[PTBR+4] = 78;
[PTBR+5] = "0110";
[PTBR+6] = 79;
[PTBR+7] = "0110";

//Code
[PTBR+8] = 65;
[PTBR+9] = "0100";
[PTBR+10] = 66;
[PTBR+11] = "0100";
[PTBR+12] = -1;
[PTBR+13] = "0000";
[PTBR+14] = -1;
[PTBR+15] = "0000";

//Stack
[PTBR+16] = 76;
[PTBR+17] = "0110";
[PTBR+18] = 77;
[PTBR+19] = "0110";

//2nd entry of header of executable contain entry point
[76*512] = [65*512 + 1];
```

```
SP = 8*512;

ireturn;
```

1. Compile and load the modified OS startup Code.

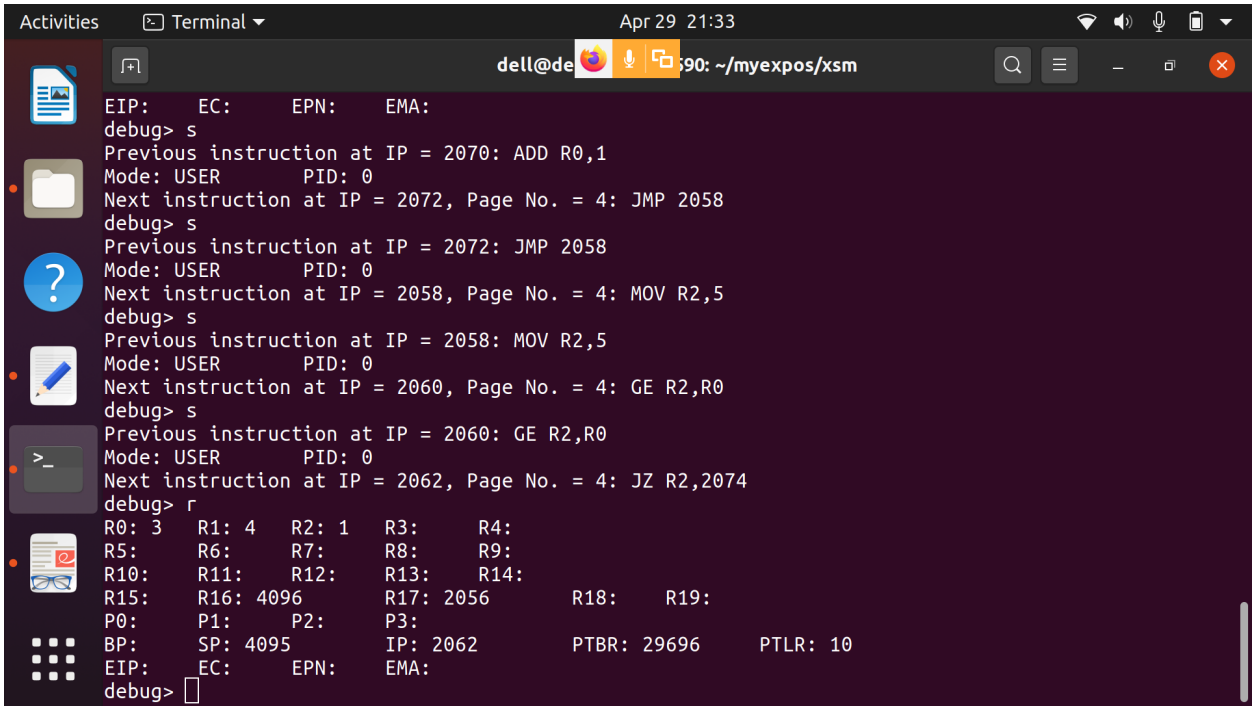
   ```
   cd $HOME/myexpos/spl

   ./spl $HOME/myexpos/spl/spl_progs/os_startup.spl

   # load --library ../expl/library.lib

   # load --os $HOME/myexpos/spl/spl_progs/os_startup.xsm

   # exit
   ```

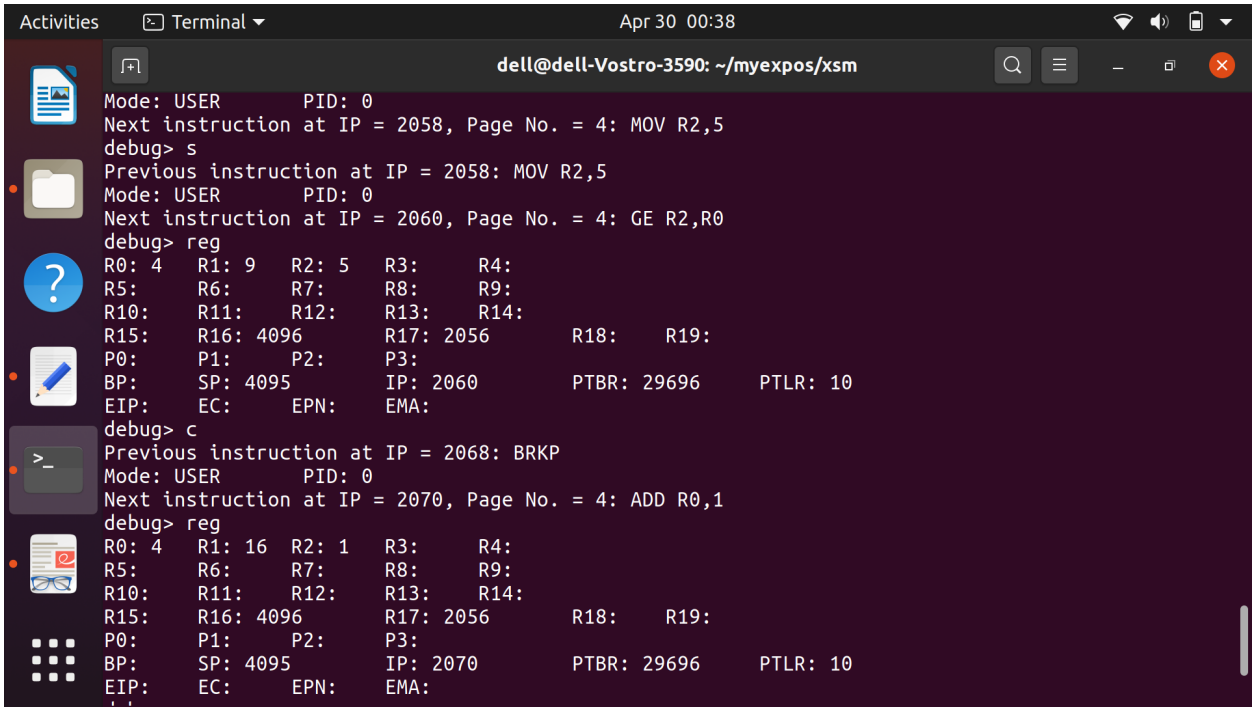
2. Load the modified user program.

   ```
   # load --init $HOME/myexpos/expl/expl_progs/squares.xsm
   ```

3. Run the machine in debug mode.

   ```
   cd $HOME/myexpos/xsm/

   ./xsm --debug --timer 0
   ```





Assignment: Change the user program to compute cubes of the first five numbers.

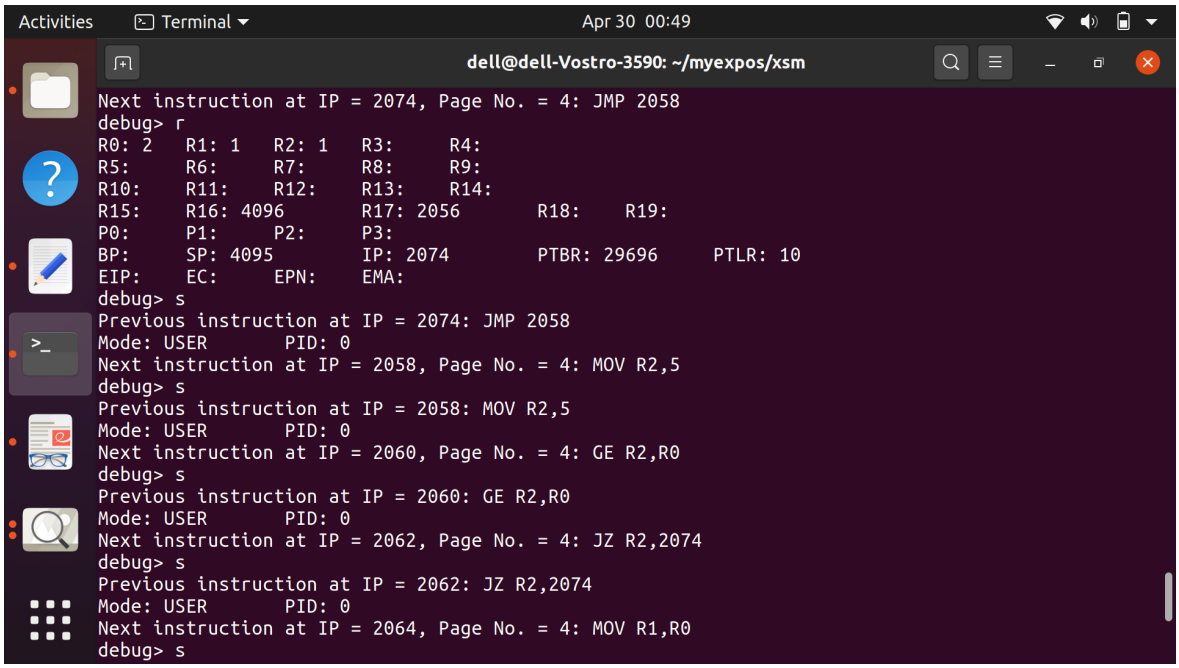
Code

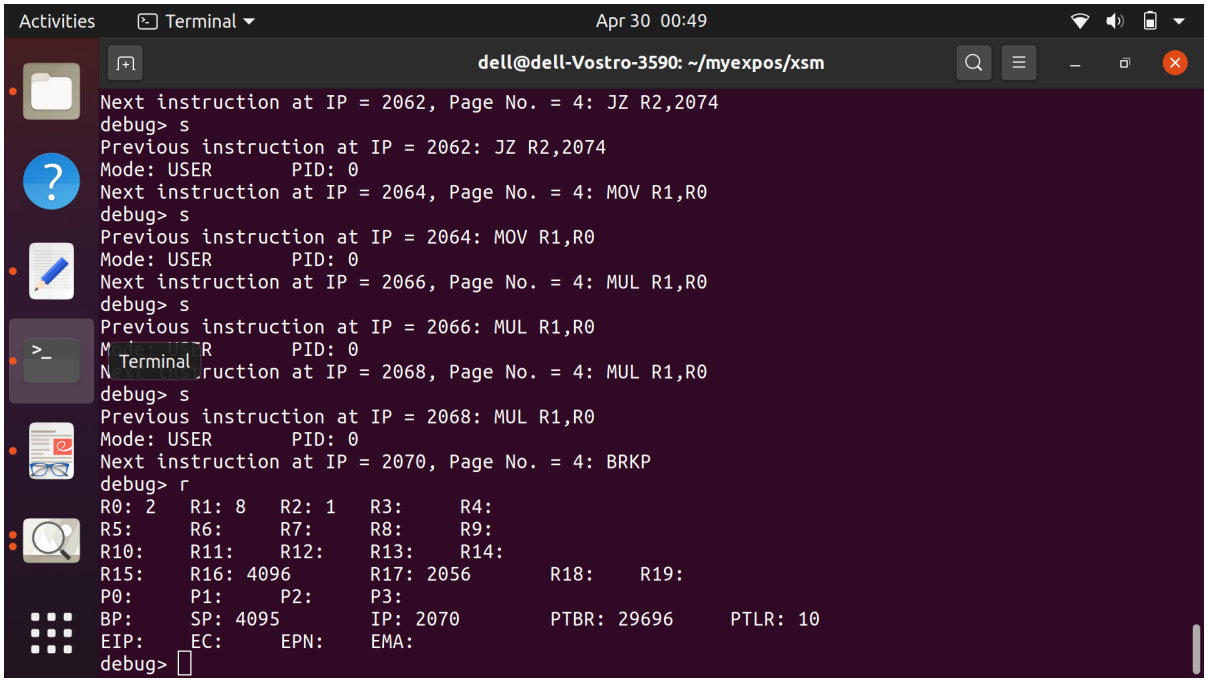
0

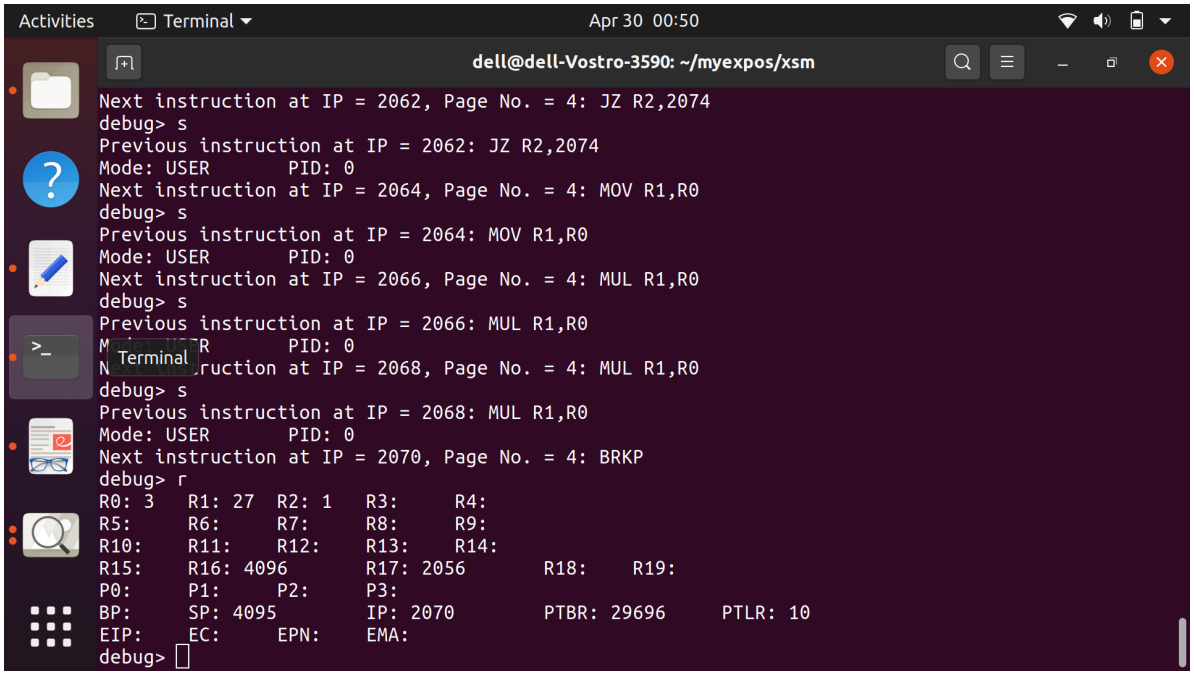
2056

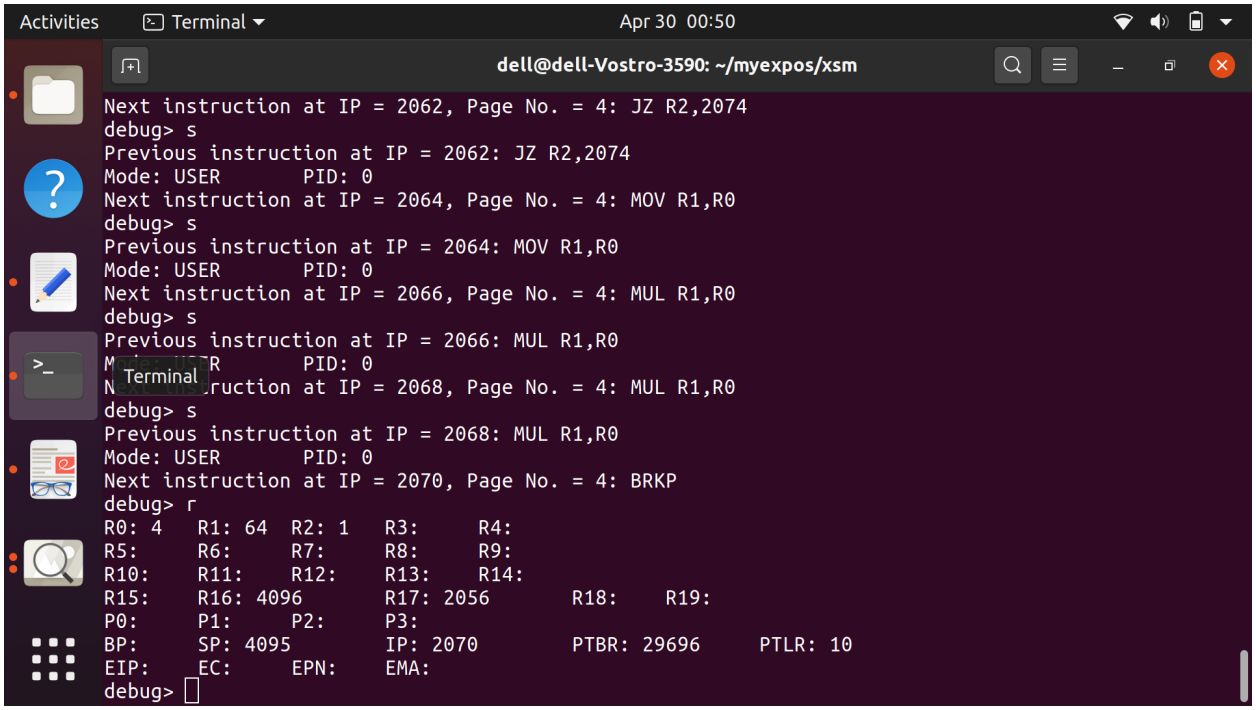
0
0
0
0
0
0
MOV R0, 1
MOV R2, 5
GE R2, R0
JZ R2, 2074
MOV R1, R0
MUL R1, R0
MUL R1, R0
BRKP
ADD R0, 1
JMP 2058
INT 10

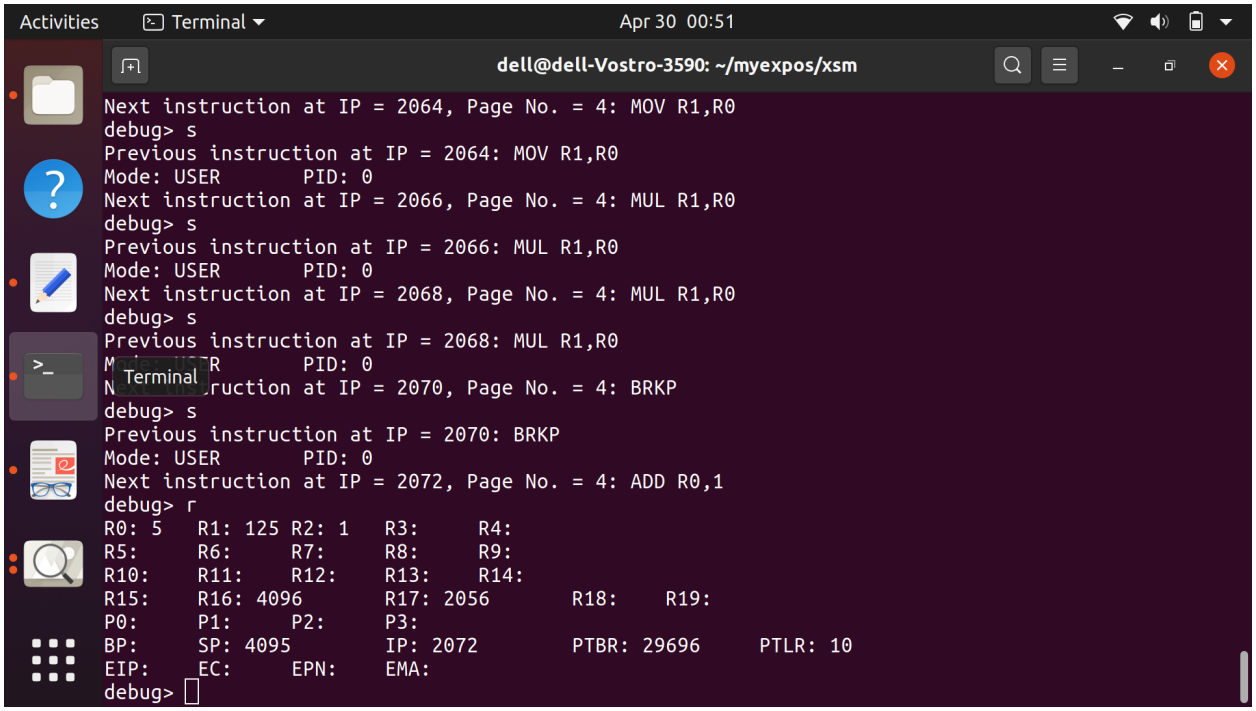
R1 stores the cube




Activities
Terminal
Apr 30 00:49
dell@dell-Vostro-3590: ~/myexpos/xsm
Terminal
Next instruction at IP = 2062, Page No. = 4: JZ R2,2074
debug> s
Previous instruction at IP = 2062: JZ R2,2074
Mode: USER PID: 0
Next instruction at IP = 2064, Page No. = 4: MOV R1,R0
debug> s
Previous instruction at IP = 2064: MOV R1,R0
Mode: USER PID: 0
Next instruction at IP = 2066, Page No. = 4: MUL R1,R0
debug> s
Previous instruction at IP = 2066: MUL R1,R0
PID: 0
Next instruction at IP = 2068, Page No. = 4: MUL R1,R0
debug> s
Previous instruction at IP = 2068: MUL R1,R0
Mode: USER PID: 0
Next instruction at IP = 2070, Page No. = 4: BRKP
debug> r
R0: 2 R1: 8 R2: 1 R3: R4:
R5: R6: R7: R8: R9:
R10: R11: R12: R13: R14:
R15: R16: 4096 R17: 2056 R18: R19:
P0: P1: P2: P3:
BP: SP: 4095 IP: 2070 PTBR: 29696 PTLR: 10
EIP: EC: EPN: EMA:
debug>


Activities
Terminal
Apr 30 00:50
dell@dell-Vostro-3590: ~/myexpos/xsm
Terminal
Next instruction at IP = 2062, Page No. = 4: JZ R2,2074
debug> s
Previous instruction at IP = 2062: JZ R2,2074
Mode: USER PID: 0
Next instruction at IP = 2064, Page No. = 4: MOV R1,R0
debug> s
Previous instruction at IP = 2064: MOV R1,R0
Mode: USER PID: 0
Next instruction at IP = 2066, Page No. = 4: MUL R1,R0
debug> s
Previous instruction at IP = 2066: MUL R1,R0
PID: 0
Next instruction at IP = 2068, Page No. = 4: MUL R1,R0
debug> s
Previous instruction at IP = 2068: MUL R1,R0
Mode: USER PID: 0
Next instruction at IP = 2070, Page No. = 4: BRKP
debug> r
R0: 3 R1: 27 R2: 1 R3: R4:
R5: R6: R7: R8: R9:
R10: R11: R12: R13: R14:
R15: R16: 4096 R17: 2056 R18: R19:
P0: P1: P2: P3:
BP: SP: 4095 IP: 2070 PTBR: 29696 PTLR: 10
EIP: EC: EPN: EMA:
debug>


Activities
Terminal
Apr 30 00:50
dell@dell-Vostro-3590: ~/myexpos/xsm
Terminal
Next instruction at IP = 2062, Page No. = 4: JZ R2,2074
debug> s
Previous instruction at IP = 2062: JZ R2,2074
Mode: USER PID: 0
Next instruction at IP = 2064, Page No. = 4: MOV R1,R0
debug> s
Previous instruction at IP = 2064: MOV R1,R0
Mode: USER PID: 0
Next instruction at IP = 2066, Page No. = 4: MUL R1,R0
debug> s
Previous instruction at IP = 2066: MUL R1,R0
PID: 0
Next instruction at IP = 2068, Page No. = 4: MUL R1,R0
debug> s
Previous instruction at IP = 2068: MUL R1,R0
Mode: USER PID: 0
Next instruction at IP = 2070, Page No. = 4: BRKP
debug> r
R0: 4 R1: 64 R2: 1 R3: R4:
R5: R6: R7: R8: R9:
R10: R11: R12: R13: R14:
R15: R16: 4096 R17: 2056 R18: R19:
P0: P1: P2: P3:
BP: SP: 4095 IP: 2070 PTBR: 29696 PTLR: 10
EIP: EC: EPN: EMA:
debug>

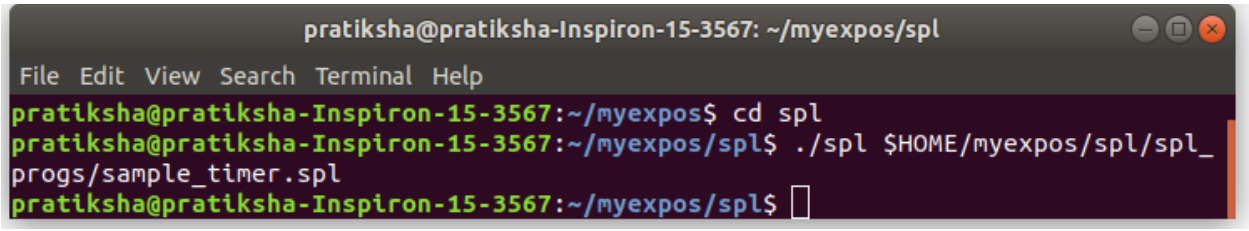

Activities
Terminal
Apr 30 00:51
dell@dell-Vostro-3590: ~/myexpos/xsm
Terminal
Next instruction at IP = 2064, Page No. = 4: MOV R1,R0
debug> s
Previous instruction at IP = 2064: MOV R1,R0
Mode: USER PID: 0
Next instruction at IP = 2066, Page No. = 4: MUL R1,R0
debug> s
Previous instruction at IP = 2066: MUL R1,R0
Mode: USER PID: 0
Next instruction at IP = 2068, Page No. = 4: MUL R1,R0
debug> s
Previous instruction at IP = 2068: MUL R1,R0
PID: 0
Next instruction at IP = 2070, Page No. = 4: BRKP
debug> s
Previous instruction at IP = 2070: BRKP
Mode: USER PID: 0
Next instruction at IP = 2072, Page No. = 4: ADD R0,1
debug> r
R0: 5 R1: 125 R2: 1 R3: R4:
R5: R6: R7: R8: R9:
R10: R11: R12: R13: R14:
R15: R16: 4096 R17: 2056 R18: R19:
P0: P1: P2: P3:
BP: SP: 4095 IP: 2072 PTBR: 29696 PTLR: 10
EIP: EC: EPN: EMA:
debug>

Stage 8) Handling timer Interrupt

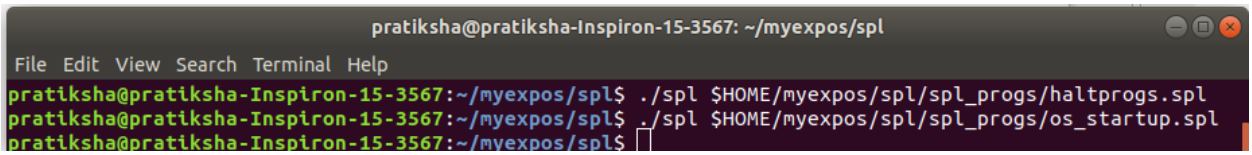
If the xsm simulator is run with the timer set to some value – say 20, then every time the machine completes the execution of 20 instructions in user mode, the timer device will send a hardware signal to interrupts the machine execution. The machine will push the IP value of the user-mode instruction to the stack and pass control to the timer interrupt handler at physical address 2048.

Modification in OS startup code:
OS startup code has to be modified to load the timer interrupt routine from disk blocks 17 and 18 to memory pages 4 and 5.
loadi(4, 17);
loadi(5, 18);

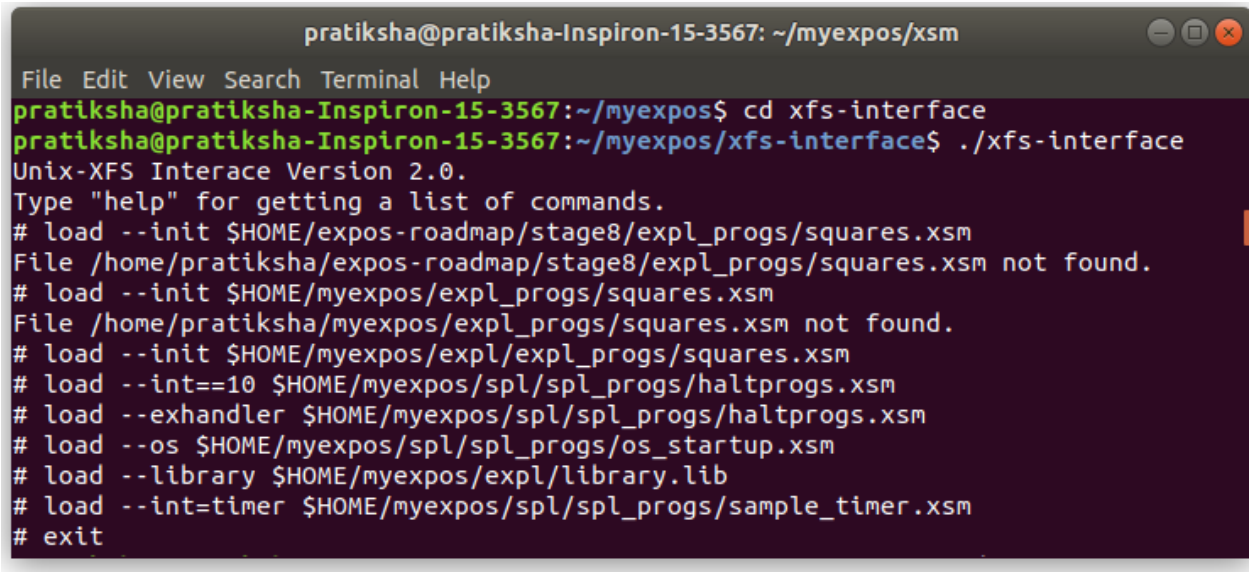
Creating a file name sample_timer.spl that prints the “TIMER” and returns it to the user program. Then compiling it. (here the user program is the same as in the previous stage)



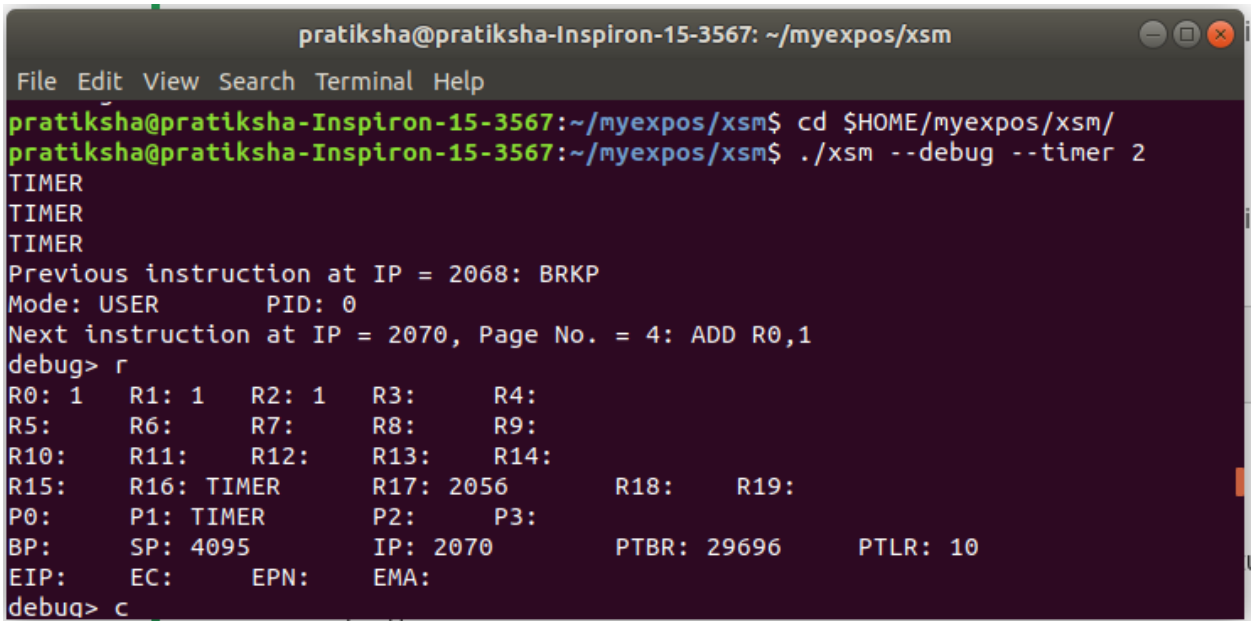
Also, compiling the os_startup and os_startup to avoid any kind of compiling error.

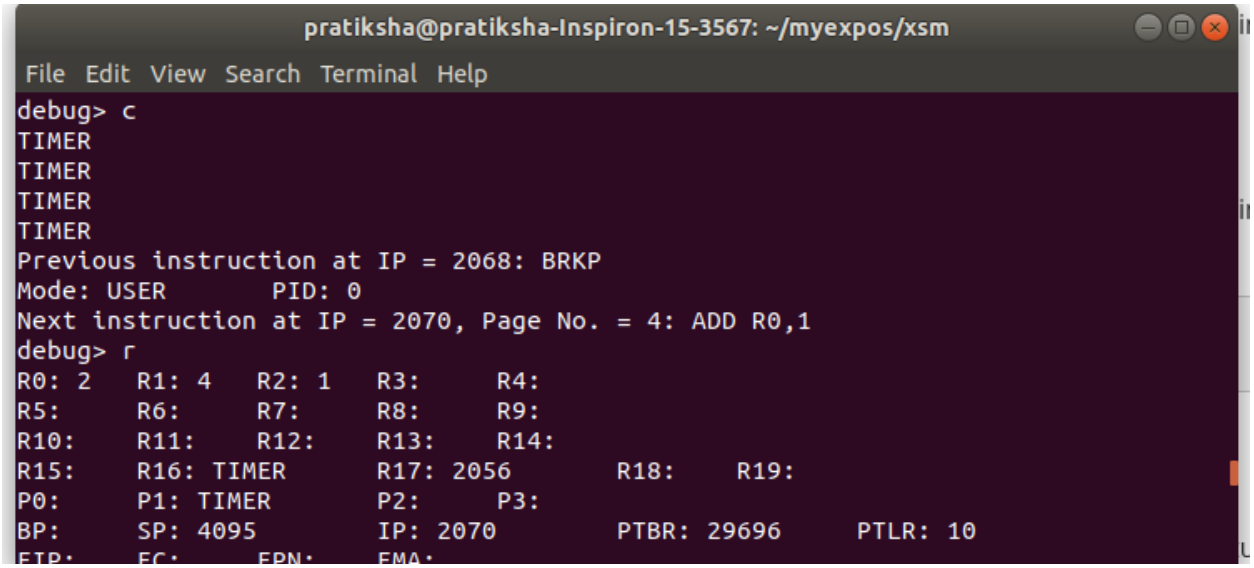


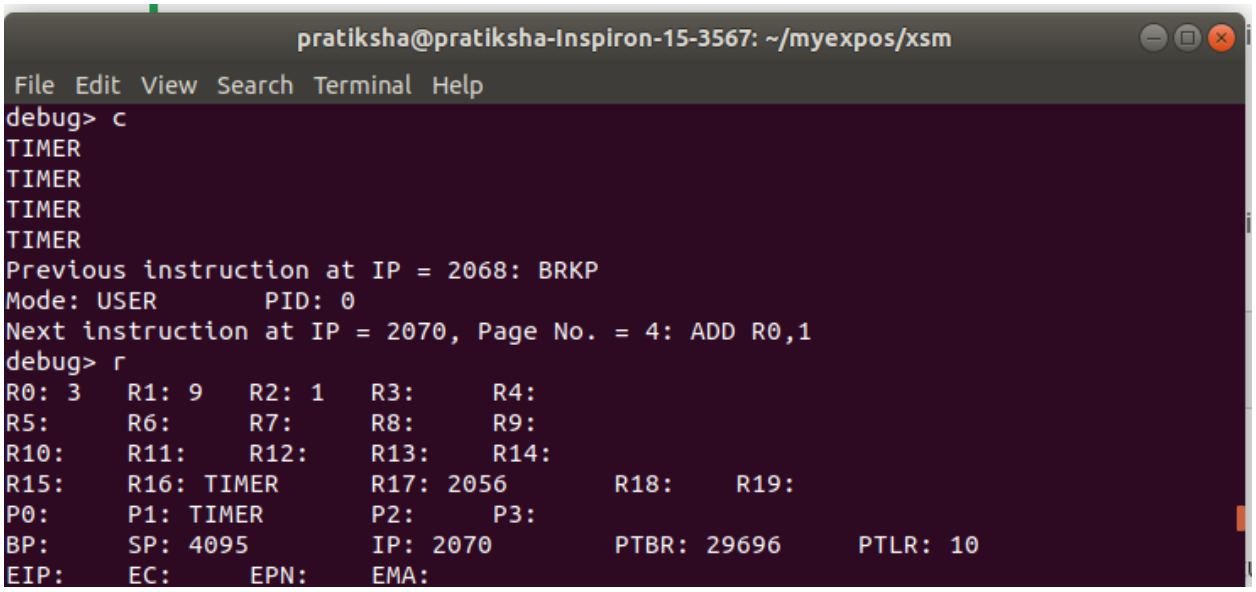
In xfs-interface, loading the process squares.xsm as init process.
Loading haltprogs.xsm with int 10.
Loading haltprogs.xsm as the interrupt handler.
Loading the os_startup.xsm in the xfs disk.
Load the library that is present in expl as library.lib.
Loading the sample_timer.xsm for int=timer.

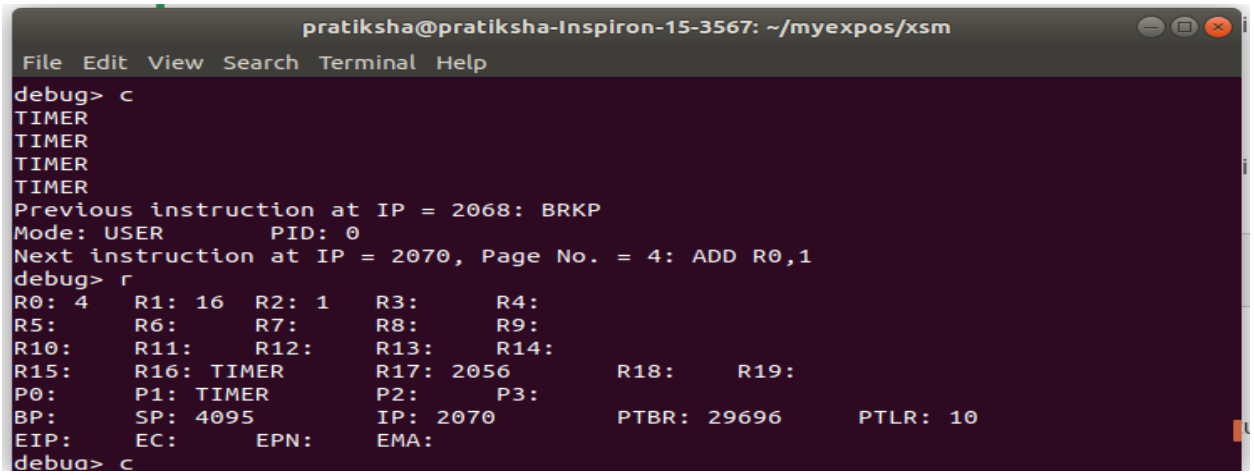


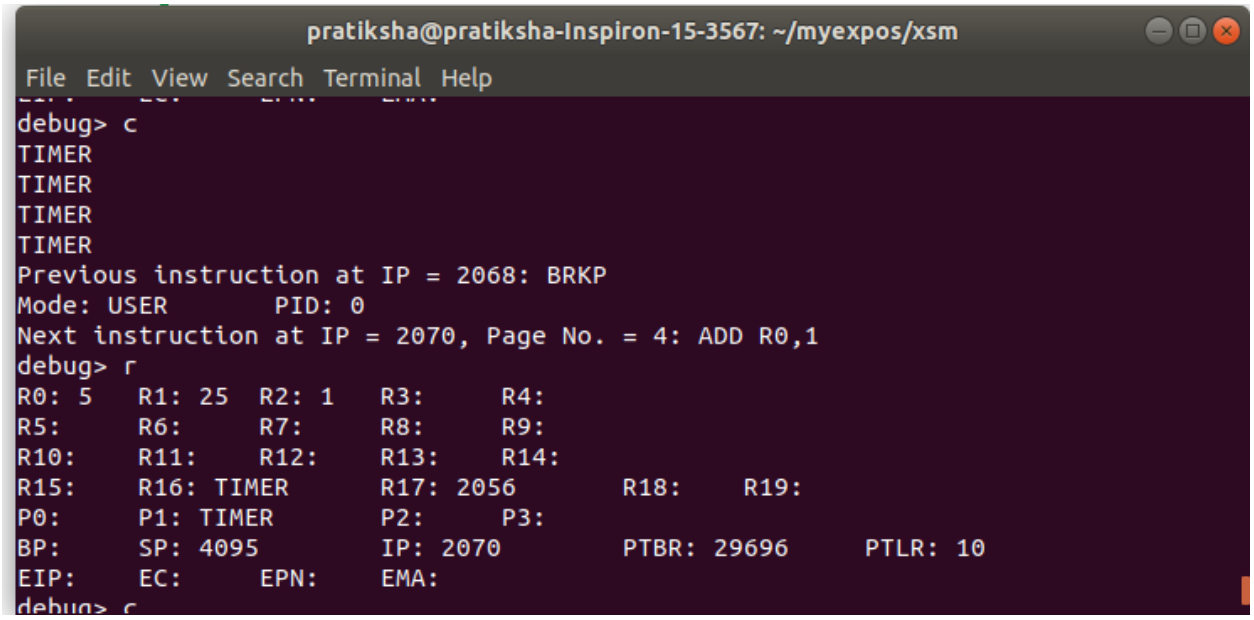
As the user program here will print the squares of first five natural numbers.




pratiksha@pratiksha-Inspiron-15-3567: ~/myexpos/xsm
File Edit View Search Terminal Help
debug> c
TIMER
TIMER
TIMER
TIMER
Previous instruction at IP = 2068: BRKP
Mode: USER PID: 0
Next instruction at IP = 2070, Page No. = 4: ADD R0,1
debug> r
R0: 2 R1: 4 R2: 1 R3: R4:
R5: R6: R7: R8: R9:
R10: R11: R12: R13: R14:
R15: R16: TIMER R17: 2056 R18: R19:
P0: P1: TIMER P2: P3:
BP: SP: 4095 IP: 2070 PTBR: 29696 PTLR: 10


pratiksha@pratiksha-Inspiron-15-3567: ~/myexpos/xsm
File Edit View Search Terminal Help
debug> c
TIMER
TIMER
TIMER
TIMER
Previous instruction at IP = 2068: BRKP
Mode: USER PID: 0
Next instruction at IP = 2070, Page No. = 4: ADD R0,1
debug> r
R0: 3 R1: 9 R2: 1 R3: R4:
R5: R6: R7: R8: R9:
R10: R11: R12: R13: R14:
R15: R16: TIMER R17: 2056 R18: R19:
P0: P1: TIMER P2: P3:
BP: SP: 4095 IP: 2070 PTBR: 29696 PTLR: 10
EIP: EC: EPN: EMA:


pratiksha@pratiksha-Inspiron-15-3567: ~/myexpos/xsm
File Edit View Search Terminal Help
debug> c
TIMER
TIMER
TIMER
TIMER
Previous instruction at IP = 2068: BRKP
Mode: USER PID: 0
Next instruction at IP = 2070, Page No. = 4: ADD R0,1
debug> r
R0: 4 R1: 16 R2: 1 R3: R4:
R5: R6: R7: R8: R9:
R10: R11: R12: R13: R14:
R15: R16: TIMER R17: 2056 R18: R19:
P0: P1: TIMER P2: P3:
BP: SP: 4095 IP: 2070 PTBR: 29696 PTLR: 10
EIP: EC: EPN: EMA:
debug> c



Page table for the corresponding process:

Memory Address	Physical Page Number	Flags
PTBR	63	0100
PTBR + 2	64	0100
PTBR + 4	78	0110
PTBR + 6	79	0110
PTBR + 8	65	0100
PTBR + 10	66	0100
PTBR + 12	-1	0000
PTBR + 14	-1	0000
PTBR + 16	76	0110
PTBR + 18	77	0110

Stage 9: Handling Kernel Stack

eXpOS requires that when the OS enters an interrupt handler that runs in kernel mode, the interrupt handler must switch to a different stack. This requirement is to prevent user level “hacks” into the kernel through the stack
To isolate the kernel from the user stack, the OS kernel must maintain two stacks for a program - **a user stack and a kernel stack**. In eXpOS, one page called the user area page is allocated for each process.

Whenever there is a transfer of program control from the user mode to the kernel during interrupts (or exceptions), the interrupt handler will change the stack to the kernel stack of the program.

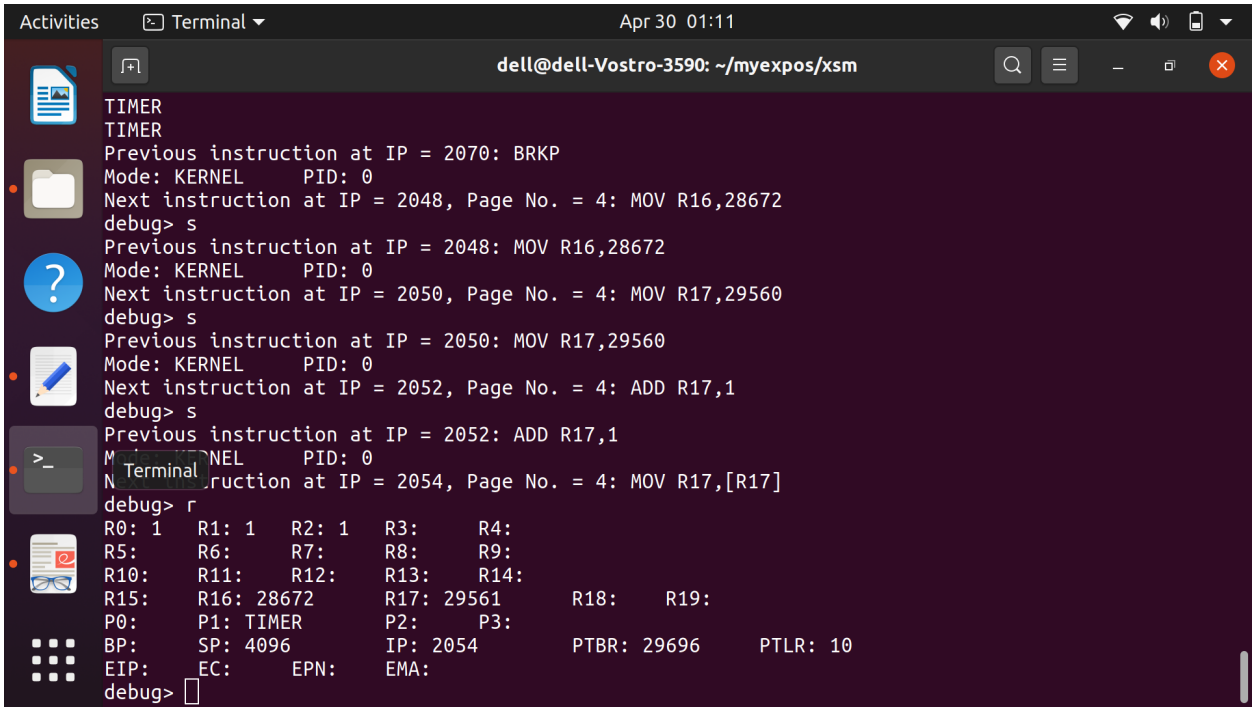
OS Startup code

```
//Loads library code from disk blocks 13 and 14 to physical pages 63 and 64
loadi(63,13);
loadi(64,14);

//Loads INIT program from 7, 8 blocks to 65, 66 physical  pages
loadi(65,7);
loadi(66,8);

//Loads interrupt routine 10 from 35, 36 blocks to  22, 23 physical pages
loadi(22,35);
loadi(23,36);

//Loads exception handler from 15, 16 blocks to 2,  3 physical pages
loadi(2, 15);
loadi(3, 16);

//Loads timer interrupt routine from 17, 18 blocks  to 4, 5 physical pages
loadi(4, 17);
loadi(5, 18);

PTBR = PAGE_TABLE_BASE;
PTLR = 10;

//Library
[PTBR+0] = 63;
[PTBR+1] = "0100";
```

```
[PTBR+2] = 64;
[PTBR+3] = "0100";

//Heap
[PTBR+4] = 78;
[PTBR+5] = "0110";
[PTBR+6] = 79;
[PTBR+7] = "0110";

//Code
[PTBR+8] = 65;
[PTBR+9] = "0100";
[PTBR+10] = 66;
[PTBR+11] = "0100";
[PTBR+12] = -1;
[PTBR+13] = "0000";
[PTBR+14] = -1;
[PTBR+15] = "0000";

//Stack
[PTBR+16] = 76;
[PTBR+17] = "0110";
[PTBR+18] = 77;
[PTBR+19] = "0110";

//2nd entry of header of executable contain entry point
[76*512] = [65*512 + 1];

SP = 8*512;

//Process table
//Setting User page area to physical page 80 (first available free page)
//Setting PID to 0
//PROCESS_TABLE = 28672
[PROCESS_TABLE + 11] = 80;
[PROCESS_TABLE + 1] = 0;

//Second field of System status table set to PID 0
[SYSTEM_STATUS_TABLE + 1] = 0;

ireturn;
```

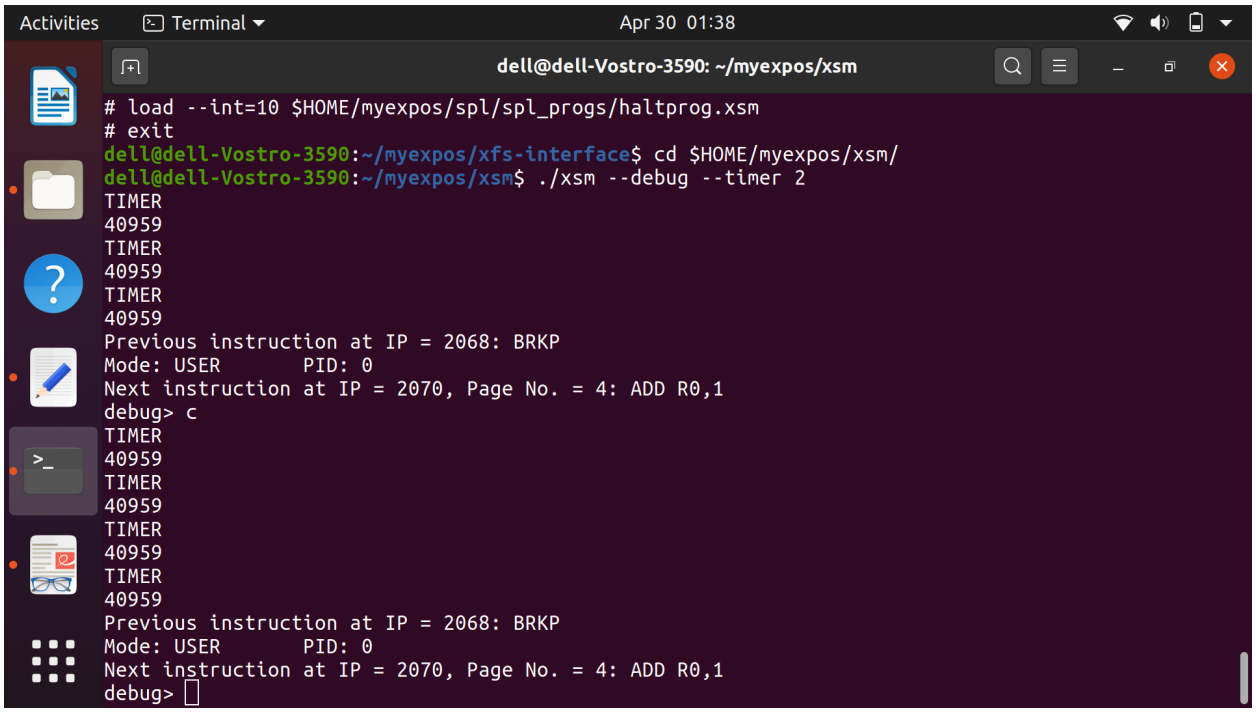
Timer Program Code

```
//PID obtained from System status table and stored in corresponding process table entry
[PROCESS_TABLE + ( [SYSTEM_STATUS_TABLE + 1] * 16) + 13] = SP;

// Setting SP to UArea Page number * 512 - 1
SP = [PROCESS_TABLE + ([SYSTEM_STATUS_TABLE + 1] * 16) + 11] * 512 - 1;

//Saving the user context
backup;

print "TIMER";

//Restoring the user context
restore;

//Setting SP to user SP saved in process table.
SP = [PROCESS_TABLE + ( [SYSTEM_STATUS_TABLE + 1] * 16) + 13];

Ireturn;
```



Assignment:- **:** Print the process id of currently executing process in timer interrupt before returning to user mode. You can look up this value from the System Status Table.

```
//PID obtained from System status table and stored in the corresponding process table entry
[PROCESS_TABLE + ( [SYSTEM_STATUS_TABLE + 1] * 16) + 13] = SP;

// Setting SP to UArea Page number * 512 - 1
SP = [PROCESS_TABLE + ([SYSTEM_STATUS_TABLE + 1] * 16) + 11] * 512 - 1;

//Saving the user context
backup;

print "TIMER";

//Restoring the user context
restore;
print SP;
//Setting SP to user SP saved in process table.
SP = [PROCESS_TABLE + ( [SYSTEM_STATUS_TABLE + 1] * 16) + 13];

Ireturn;
```



Stage 10: Console output

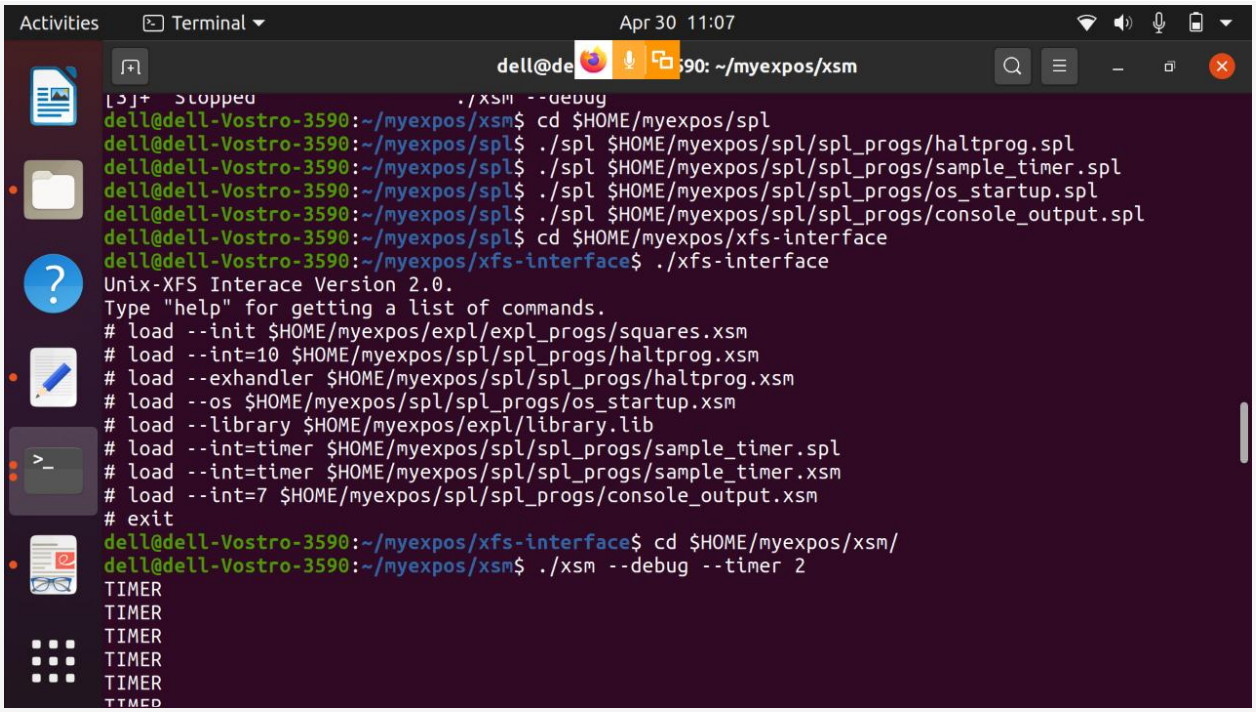
In this stage, we will rewrite the user program to enable it to write to the terminal. The primary data structures we are concerned with here are the system status table, process table, and page table. The write system call is serviced by interrupt routine 7.

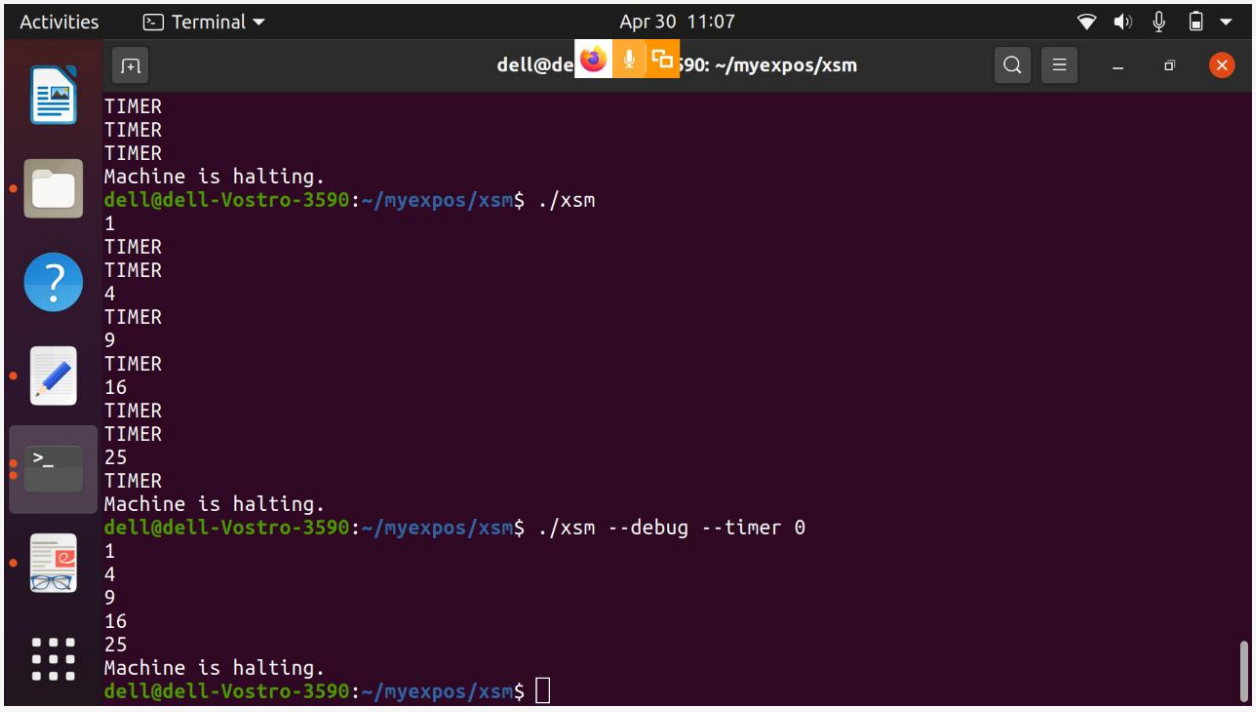
A system call is an OS routine that can be invoked from a user program. The OS provides system call routines for various services like writing to a file/console, forking a process, etc. Each system call routine is written inside some software interrupt handler.

Console_output.spl

The interrupt 7 routine programs are used for printing to the terminal screen. This program requires 3 arguments- argument 1 is -2 (file descriptor for terminal), argument 2 is the value to be printed, and argument 3 is could be anything (exists solely for the convention). If argument 1 is -2, prints value to the terminal, else, returns -1.

The output of squares.xsm -





Question -

Why should we calculate the physical address of userSP-3 and userSP-1 separately instead of calculating one and adding/subtracting the difference from the calculated value?

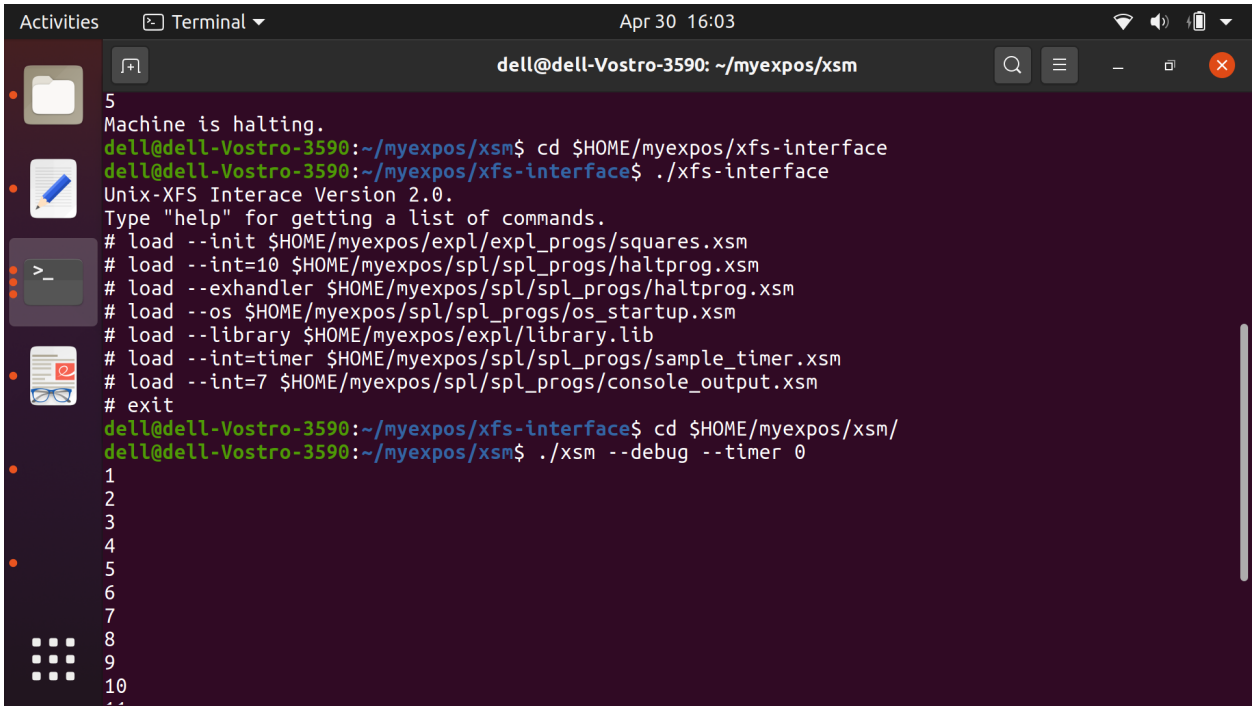
Answer -

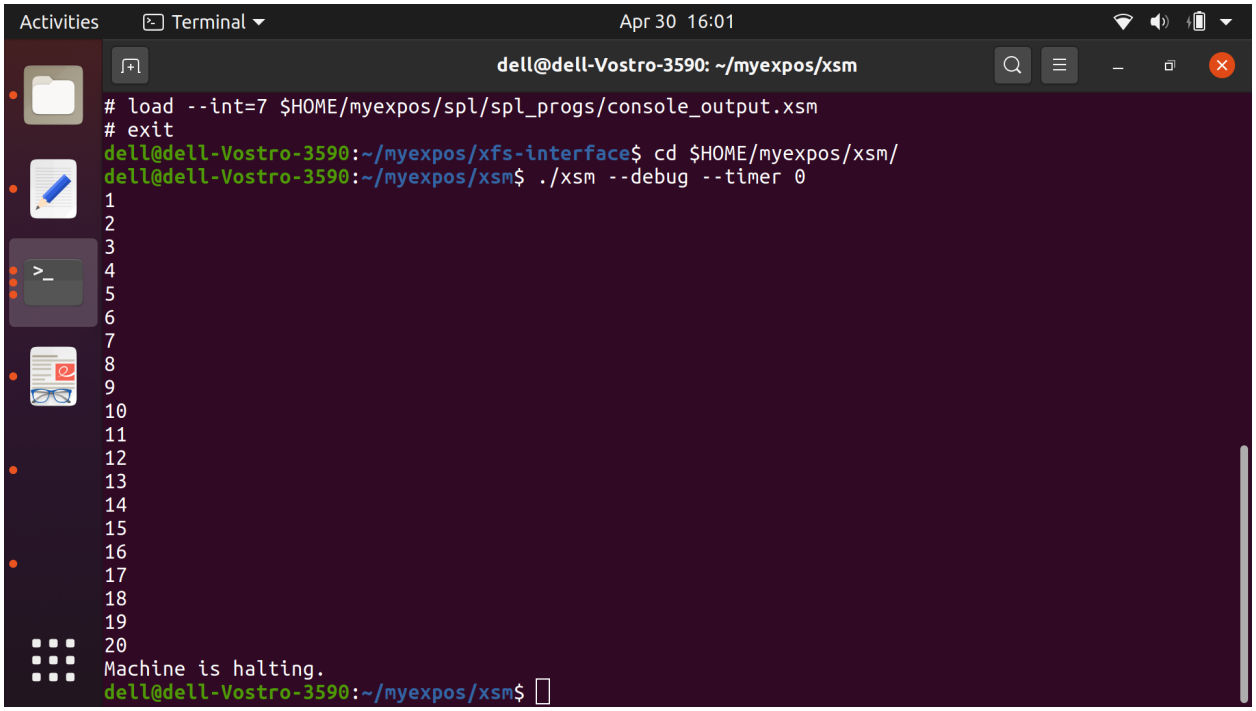
Suppose the physical address corresponding to the logical address in userSP be - say 3000. it may not be the case that 2997 is the physical address corresponding to the logical address userSP-3. Similarly, the physical address corresponding to userSP-1 need not be 2999. The problem is that the stack of a process spreads over two pages, and these two physical pages need not be contiguous. Hence logical addresses can not be calculated in such a way.

Assignment 1: Write a program to print the first 20 numbers and run the system with a timer enabled.

Program files have been uploaded to google classroom.

Output - First 20 numbers (1,2,3…,20) are printed on the terminal.


Activities
Terminal
Apr 30 16:03
dell@dell-Vostro-3590: ~/myexpos/xsm
5
Machine is halting.
dell@dell-Vostro-3590:~/myexpos/xsm$ cd $HOME/myexpos/xfs-interface
dell@dell-Vostro-3590:~/myexpos/xfs-interface$ ./xfs-interface
Unix-XFS Interace Version 2.0.
Type "help" for getting a list of commands.
load --init $HOME/myexpos/expl/expl_progs/squares.xsm
load --int=10 $HOME/myexpos/spl/spl_progs/haltprog.xsm
load --exhandler $HOME/myexpos/spl/spl_progs/haltprog.xsm
load --os $HOME/myexpos/spl/spl_progs/os_startup.xsm
load --library $HOME/myexpos/expl/library.lib
load --int=timer $HOME/myexpos/spl/spl_progs/sample_timer.xsm
load --int=7 $HOME/myexpos/spl/spl_progs/console_output.xsm
exit
dell@dell-Vostro-3590:~/myexpos/xfs-interface$ cd $HOME/myexpos/xsm/
dell@dell-Vostro-3590:~/myexpos/xsm$ ./xsm --debug --timer 0
1
2
3
4
5
6
7
8
9
10


Activities
Terminal
Apr 30 16:01
dell@dell-Vostro-3590: ~/myexpos/xsm
load --int=7 $HOME/myexpos/spl/spl_progs/console_output.xsm
exit
dell@dell-Vostro-3590:~/myexpos/xfs-interface$ cd $HOME/myexpos/xsm/
dell@dell-Vostro-3590:~/myexpos/xsm$ ./xsm --debug --timer 0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Machine is halting.
dell@dell-Vostro-3590:~/myexpos/xsm$