Machine Problem 3: Page Table Management

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CPSC611: Operating System

The goal of this assignment is the implementation of a demand-paging based virtual memory system for a kernel, focusing on the paging mechanism of the x86 architecture. It aims for the setup and initialization of the paging system and page table infrastructure for managing memory, initially for a single address space, with the prospect of extending to multiple processes and address spaces. This involves changes in page table management, handling page faults, and understanding the memory layout and management within a kernel environment.
We work on handling modest amounts of memory, enabling us to maintain the page table directly in physical memory. As mentioned in the Machine problem handout, this setup serves as a precursor to more advanced exercises where the page table itself will be managed in virtual memory.

In this machine problem, we have created a manager for handling page frames in the memory system of an x86 architecture-based machine. This manager is built on a hierarchical structure with two levels: the "page directory" at the top level and the "page table" at the second level. Each of these tables contain entries that are 32 bits in length, with the first 10 bits dedicated to navigation within the page directory, the next 10 bits for navigation within the page table, and the final 12 bits designated for the offset inside the physical memory frame. The designed paging mechanism is prepared to allocate pages to processes and adeptly manage page faults should they occur.

Assigned Task

Completed

Code Description

I made modifications to the files "page_table.c," "cont_frame_pool.c" and "cont_frame_pool.h". The codes for “cont_frame_pool.c” and “cont_frame_pool.h” were reused from the machine problem 2. To compile the modified code, the provided makefile should be executed. So I run the commands mentioned in compilation section of this document. For simulating the environment, the "copykernel.sh" script is used, followed by initiating the Bochs simulator with the command "bochs -f bochsrc.bxrc".

init paging : Initializes the static variables of the PageTable.

The PageTable constructor initially creates a page table tailored for directly mapped memory aligned with the kernel pool. Within this table, all pages are marked as "VALID" and granted "READ/WRITE" permissions. Conversely, the other frames are set to "INVALID" status, earmarked for user-level operations. For the page directory, only the first entry is marked as valid, with all subsequent entries being deemed invalid.

The "load" function initialises the current page table to reflect the current page table object and sets up the CR3 register with the active page directory.

Page fault handling falls under the purview of the "handle_fault" function. It initially looks up the error code in the REGS structure to see if the interruption it received is related to a page fault. The CR2 register contains the address that is generating the issue. The indices for the page directory and page table are calculated using this address. A new frame is allocated for the directory entry in the event that it is determined to be invalid, hence initialising a new page table. Next, the page table entry's validity is verified. In the event that it is invalid, a frame is also allocated for this entry, which is equivalent to assigning a page from the process pool that the page table entry would reference.

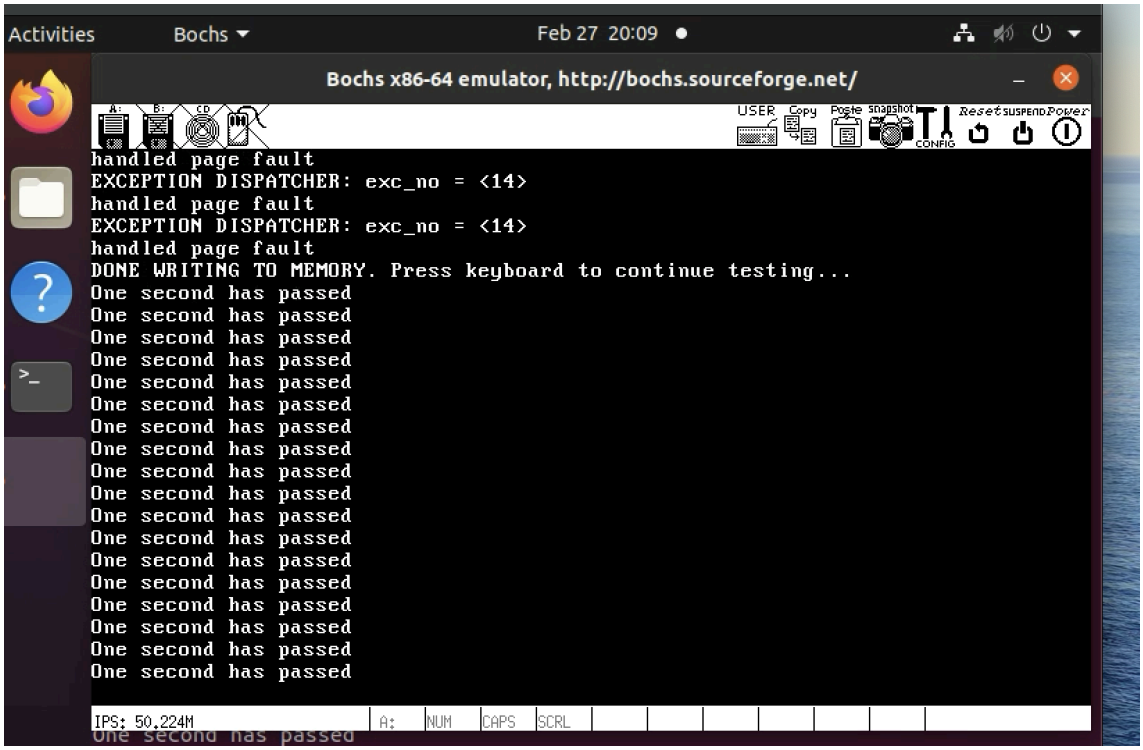
Compilation

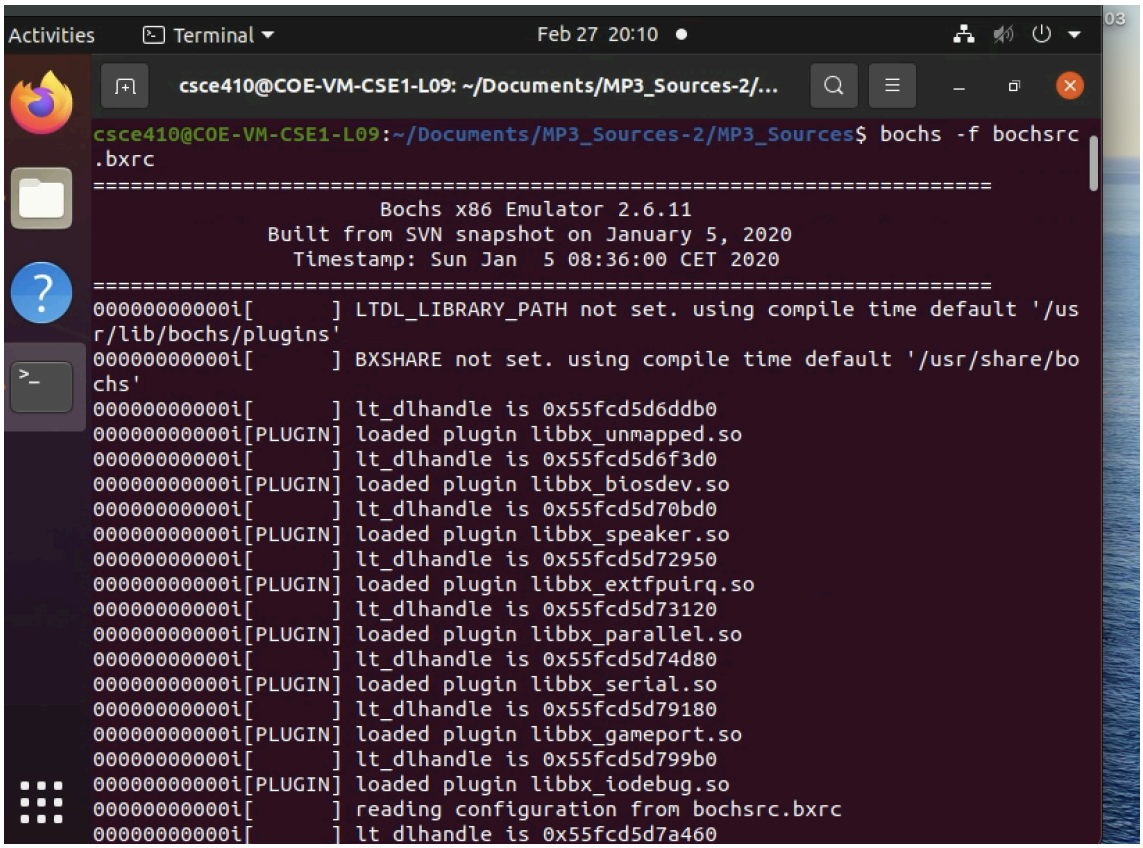
To compile the code, we run the following commands:

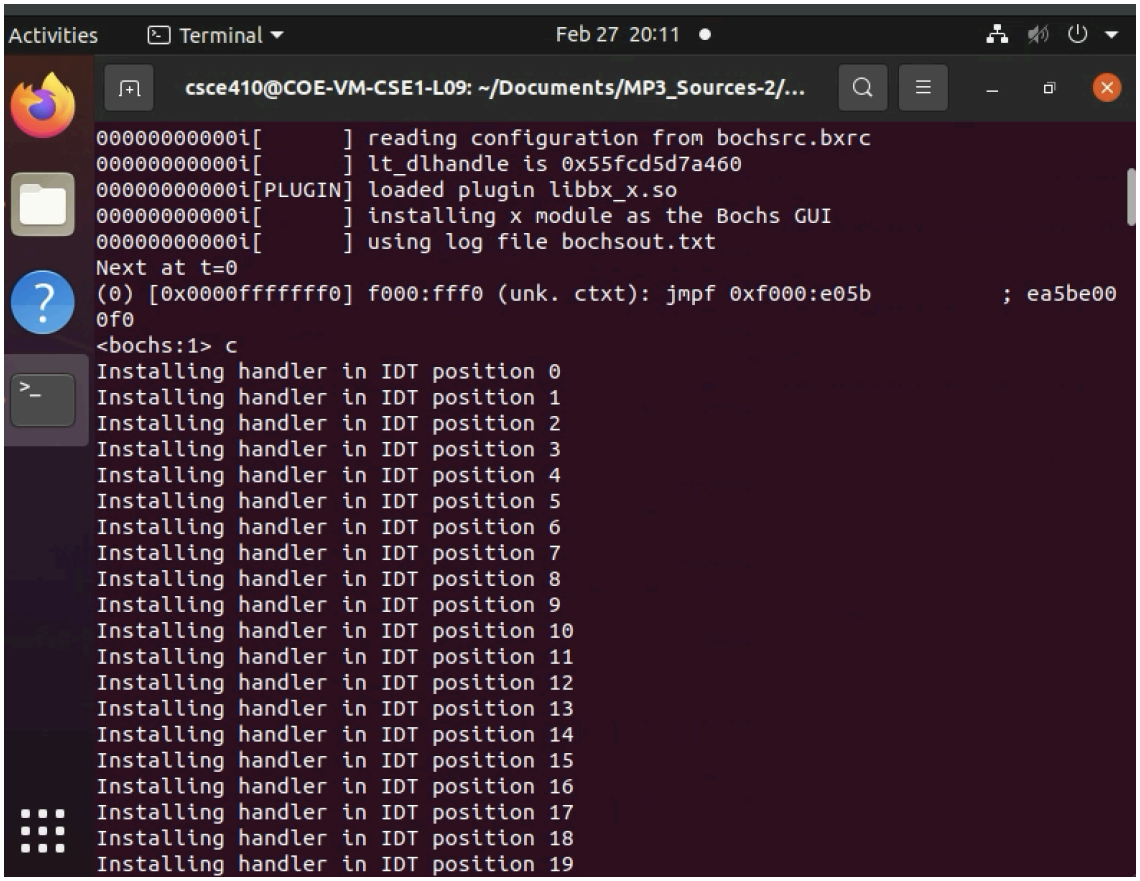
```
make clean
make
./copykernel.sh
bochs –f bochsrc.bxrc
```

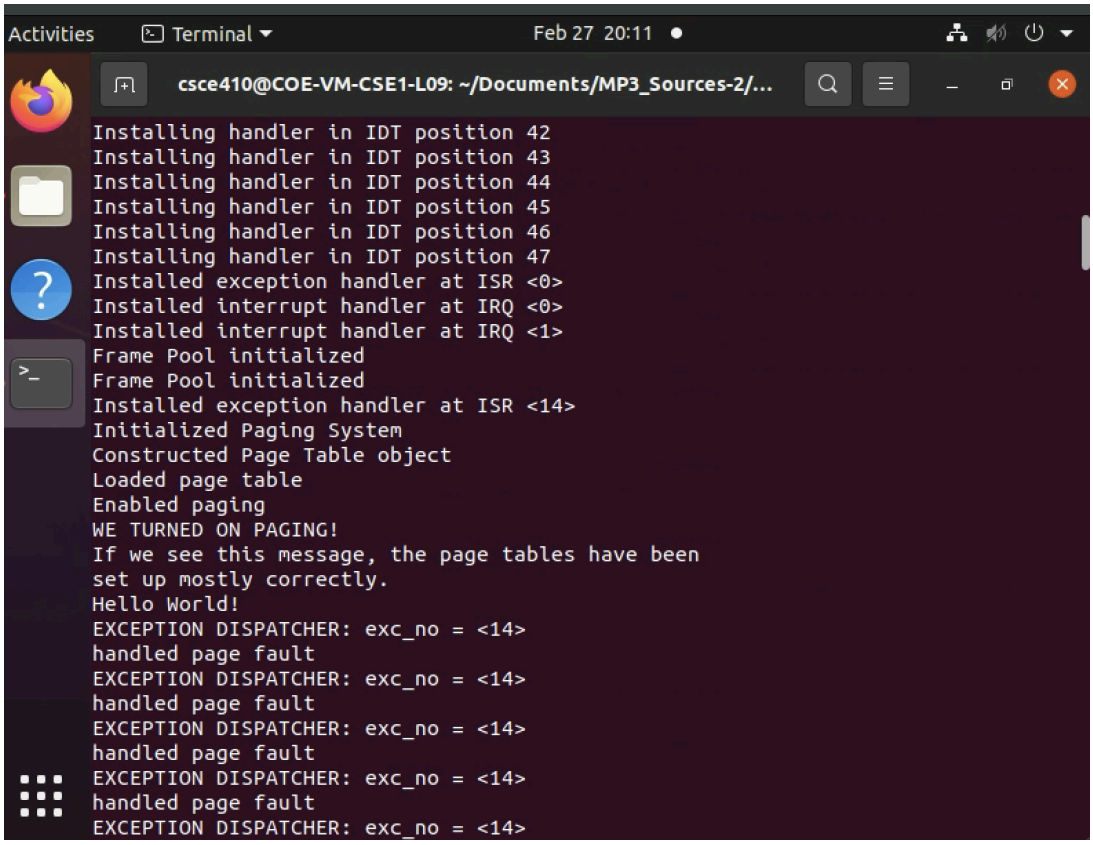
Testing

All the tests are passing, for given and additional scenarios. I have attached the screenshot if the output I got.


Activities
Bochs
Feb 27 20:09
Bochs x86-64 emulator, http://bochs.sourceforge.net/
handled page fault
EXCEPTION DISPATCHER: exc_no = <14>
handled page fault
EXCEPTION DISPATCHER: exc_no = <14>
handled page fault
DONE WRITING TO MEMORY. Press keyboard to continue testing...
One second has passed
IPS: 50.224M


Activities
Terminal
Feb 27 20:10
csce410@COE-VM-CSE1-L09: ~/Documents/MP3_Sources-2/...
csce410@COE-VM-CSE1-L09:~/Documents/MP3_Sources-2/MP3_Sources$ bochs -f bochsrc.bxrc
Bochs x86 Emulator 2.6.11
Built from SVN snapshot on January 5, 2020
Timestamp: Sun Jan 5 08:36:00 CET 2020
00000000000i[ ] LTDL_LIBRARY_PATH not set. using compile time default '/usr/lib/bochs/plugins'
00000000000i[ ] BXSHARE not set. using compile time default '/usr/share/bochs'
00000000000i[ ] lt_dlhandle is 0x55fcd5d6ddb0
00000000000i[PLUGIN] loaded plugin libbx_unmapped.so
00000000000i[ ] lt_dlhandle is 0x55fcd5d6f3d0
00000000000i[PLUGIN] loaded plugin libbx_biosdev.so
00000000000i[ ] lt_dlhandle is 0x55fcd5d70bd0
00000000000i[PLUGIN] loaded plugin libbx_speaker.so
00000000000i[ ] lt_dlhandle is 0x55fcd5d72950
00000000000i[PLUGIN] loaded plugin libbx_extfpuirq.so
00000000000i[ ] lt_dlhandle is 0x55fcd5d73120
00000000000i[PLUGIN] loaded plugin libbx_parallel.so
00000000000i[ ] lt_dlhandle is 0x55fcd5d74d80
00000000000i[PLUGIN] loaded plugin libbx_serial.so
00000000000i[ ] lt_dlhandle is 0x55fcd5d79180
00000000000i[PLUGIN] loaded plugin libbx_gameport.so
00000000000i[ ] lt_dlhandle is 0x55fcd5d799b0
00000000000i[PLUGIN] loaded plugin libbx_iodebug.so
00000000000i[ ] reading configuration from bochsrc.bxrc
00000000000i[ ] lt_dlhandle is 0x55fcd5d7a460


Activities
Terminal
Feb 27 20:11
csce410@COE-VM-CSE1-L09: ~/Documents/MP3_Sources-2/...
00000000000i[ ] reading configuration from bochsrc.bxrc
00000000000i[ ] lt_dlhandle is 0x55fcd5d7a460
00000000000i[PLUGIN] loaded plugin libbx_x.so
00000000000i[ ] installing x module as the Bochs GUI
00000000000i[ ] using log file bochsout.txt
Next at t=0
(0) [0x0000fffffff0] f000:fff0 (unk. ctxt): jmpf 0xf000:e05b ; ea5be00
0f0
<bochs:1> c
Installing handler in IDT position 0
Installing handler in IDT position 1
Installing handler in IDT position 2
Installing handler in IDT position 3
Installing handler in IDT position 4
Installing handler in IDT position 5
Installing handler in IDT position 6
Installing handler in IDT position 7
Installing handler in IDT position 8
Installing handler in IDT position 9
Installing handler in IDT position 10
Installing handler in IDT position 11
Installing handler in IDT position 12
Installing handler in IDT position 13
Installing handler in IDT position 14
Installing handler in IDT position 15
Installing handler in IDT position 16
Installing handler in IDT position 17
Installing handler in IDT position 18
Installing handler in IDT position 19


Activities
Terminal
Feb 27 20:11
csce410@COE-VM-CSE1-L09: ~/Documents/MP3_Sources-2/...
Installing handler in IDT position 42
Installing handler in IDT position 43
Installing handler in IDT position 44
Installing handler in IDT position 45
Installing handler in IDT position 46
Installing handler in IDT position 47
Installed exception handler at ISR <0>
Installed interrupt handler at IRQ <0>
Installed interrupt handler at IRQ <1>
Frame Pool initialized
Frame Pool initialized
Installed exception handler at ISR <14>
Initialized Paging System
Constructed Page Table object
Loaded page table
Enabled paging
WE TURNED ON PAGING!
If we see this message, the page tables have been
set up mostly correctly.
Hello World!
EXCEPTION DISPATCHER: exc_no = <14>
handled page fault
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handled page fault
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handled page fault
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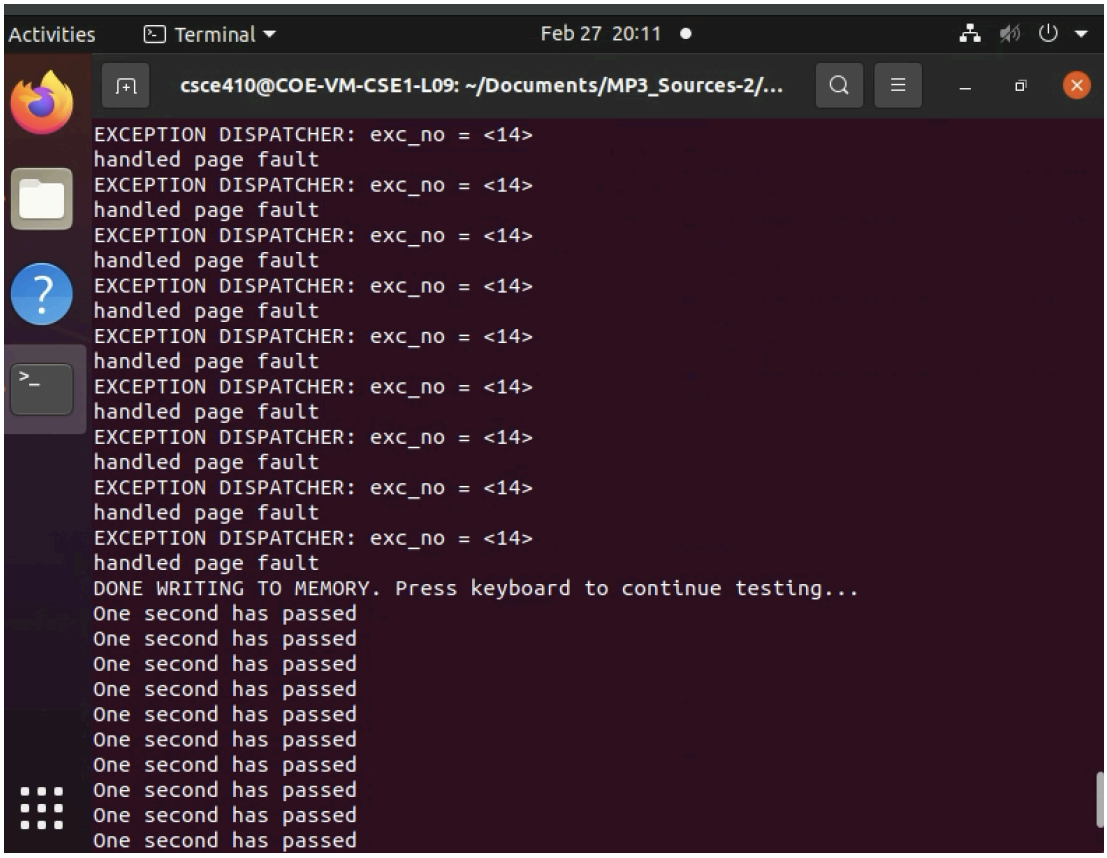
handled page fault
EXCEPTION DISPATCHER: exc_no = <14>


Activities
Terminal
Feb 27 20:11
csce410@COE-VM-CSE1-L09: ~/Documents/MP3_Sources-2/...
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handled page fault
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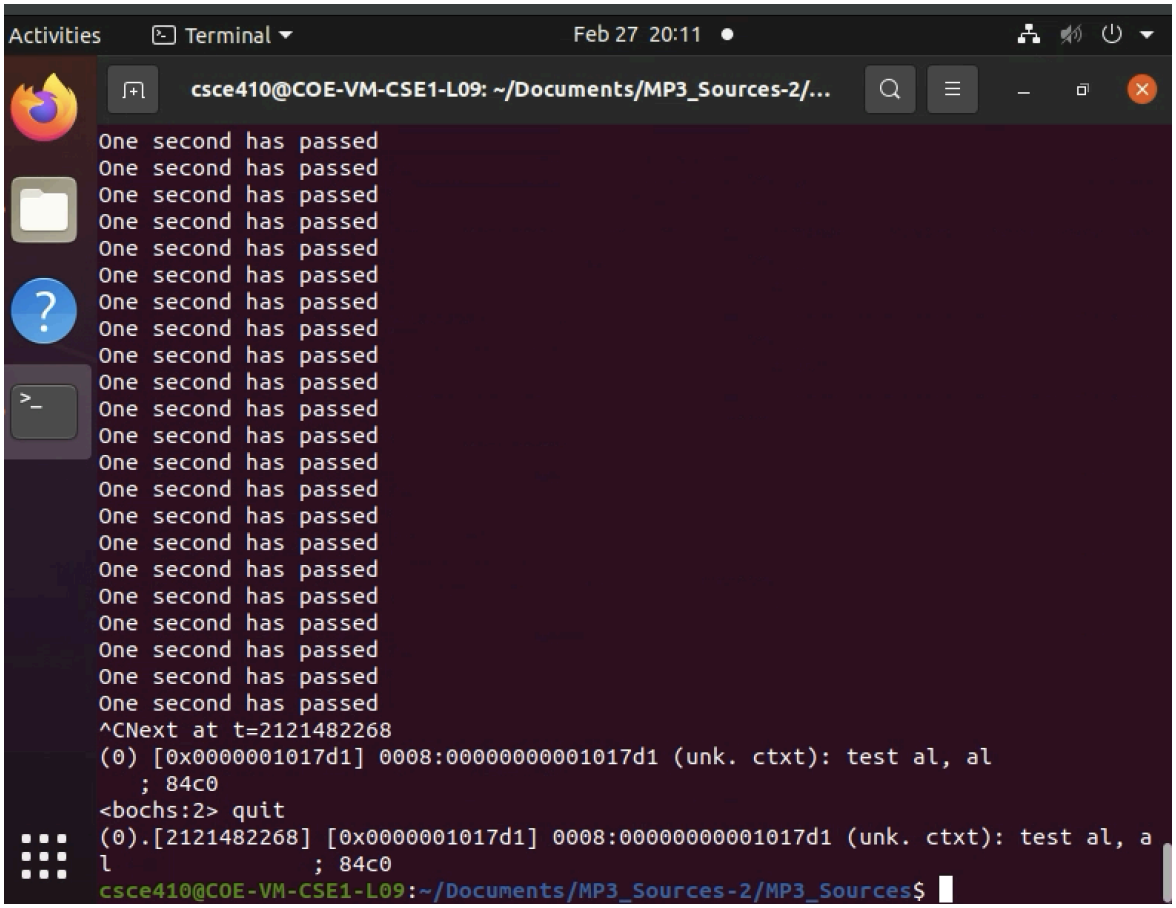
handled page fault
DONE WRITING TO MEMORY. Press keyboard to continue testing...
One second has passed
One second has passed
One second has passed
One second has passed
One second has passed
One second has passed
One second has passed
One second has passed
One second has passed
One second has passed


Activities
Terminal
Feb 27 20:11
csce410@COE-VM-CSE1-L09: ~/Documents/MP3_Sources-2/...
One second has passed
One second has passed
One second has passed
One second has passed
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One second has passed
One second has passed
One second has passed
^CNext at t=2121482268
(0) [0x0000001017d1] 0008:0000000001017d1 (unk. ctxt): test al, al
; 84c0
<bochs:2> quit
(0).[2121482268] [0x0000001017d1] 0008:0000000001017d1 (unk. ctxt): test al, a
l ; 84c0
csce410@COE-VM-CSE1-L09:~/Documents/MP3_Sources-2/MP3_Sources$