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UNIVERSITY OF BUEA

DEPARTMENT OF COMPUTER ENGENEERING

COURSE: OPERATING SYSTEM

COURSE CODE: CEF347

REQUIREMENT, ANALYSIS, DESIGN, IMPLEMENTATION OF AN OPERATING SYSTEM

Report presented and agreed upon by group 18members

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On Sunday 08-January-2023

AIM: **To Design an operating System**

Introduction:

An Operating System is a system software used to link the application software to the hardware. An operating system is made up of the following parts:

1. **The Shell**
   - ❖ The Shell is a collection of Commands.
   - ❖ The Shell acts as an interface between the user and the kernel.
   - ❖ The Shell is a Command Line Interpreter-Translate the commands provided by the user and converts it into a language that is understood by the Kernel.
   - ❖ Only one Kernel running on the system, but several shells in action-one for each user who is logged in.
   - ❖ E.g.: C Shell, Bourne Shell, Korn Shell etc.
2. **The Kernel**
   - ❖ The Kernel is the heart of the Operating System
   - ❖ It interfaces between Shell and Hardware.
   - ❖ It performs Low Level Task.
   - ❖ E.g. Device Management, Memory Management etc.
3. **Files and Processes**
   - ❖ A File is an array of bytes and can contain anything.
   - ❖ All data is organized into files.
   - ❖ A process is a program file under execution.
   - ❖ Files and Processes belongs to a separate hierarchical structure.
4. **System Calls**
   - ❖ Thousands of commands in the system uses a handful of functions called System Calls to communicate with the kernel.

We are going to present our operating system in this work

Requirement:

To build our operating system, we used different software to perform different tasks. Here are the different software we used to develop our operating system:

1. QEMU
2. HEX EDITOR
3. NOTEPAD++
4. NASM
5. SASM
6. CODE::BLOCKS

Requirement Analysis :

1. **QEMU:**
   To run the operating system we develop, we have used an Emulator named QEMU
2. **HEX EDITOR:**
   Used to see the hexadecimal output o
3. **NOTEPAD++:**
   Used to write assembly language codes which are later stored as SASM
4. **NASM:**
   NASM is a widely used assembler. NASM was used as our assembler.
5. **SASM:**
   SASM is an ide which helps build assembly programs easily. SASM was used to write all our assembly codes
6. **CODE::BLOCKS:**
   An ide used for compiling C programs. We used CODE::BLOCKS to write and compile our C programs.

After downloading the above applications, we set up our environment variables

Design:

The design of our operating system was done by coding the following commands chronologically

❖ **Boot Sector**:

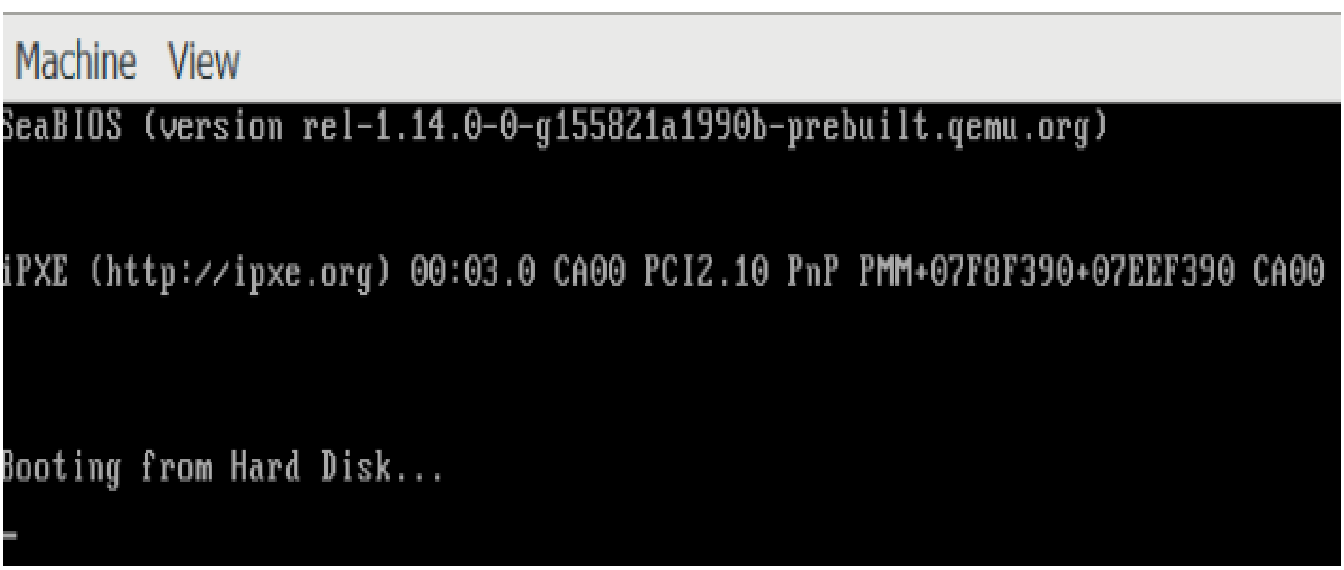
Boot Sector is a 512 bytes location in the Hard Disk where we placed the codes that we ran. To be able to boot a file we typed the following commands in the command prompt:

1. To tell the computer it is an executable file, we typed the following code in sasm an assembled it:

```
loop:
    jmp loop
    times 510-($-$$) db 0
    dw 0xaa55
```

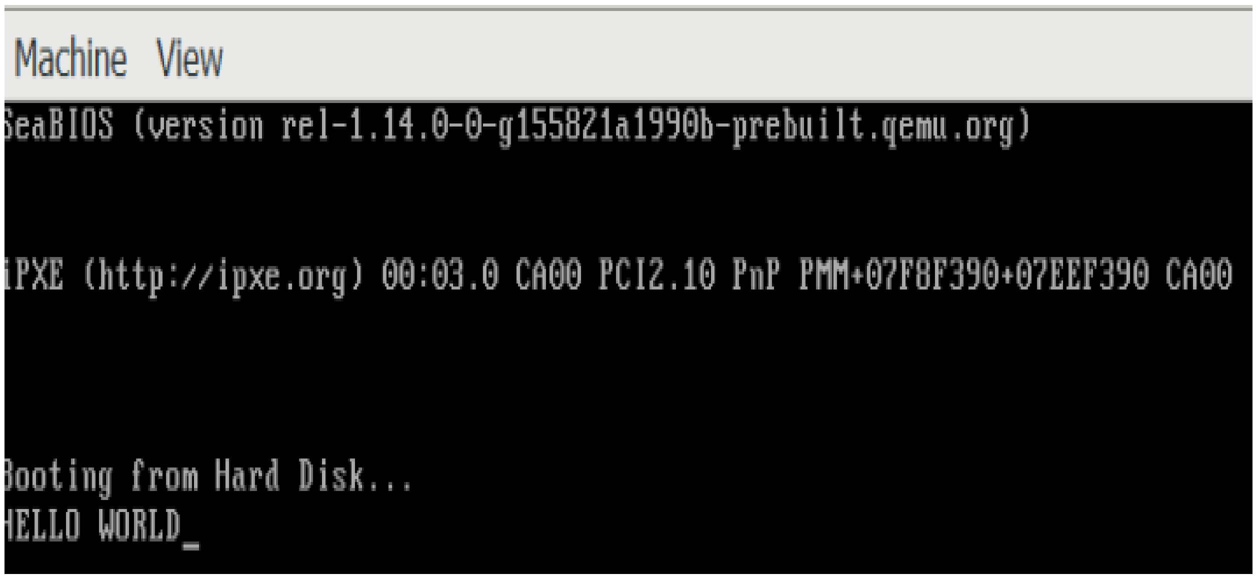
2. To create a bootable file, we typed: nasm boot-sect0.asm -f bin -o filename.
3. To both the file, we typed: qemu-system-i386 -drive format=raw ,file=filename.

   After the following operations our output was as follows:



- **Printing to the screen:**

  Here we printed ***hello world*** to the screen by writing and assembly code to move data into some 16 bit registers, with our computer initially in 16 bit mode after boot-up. Our output was as follows:

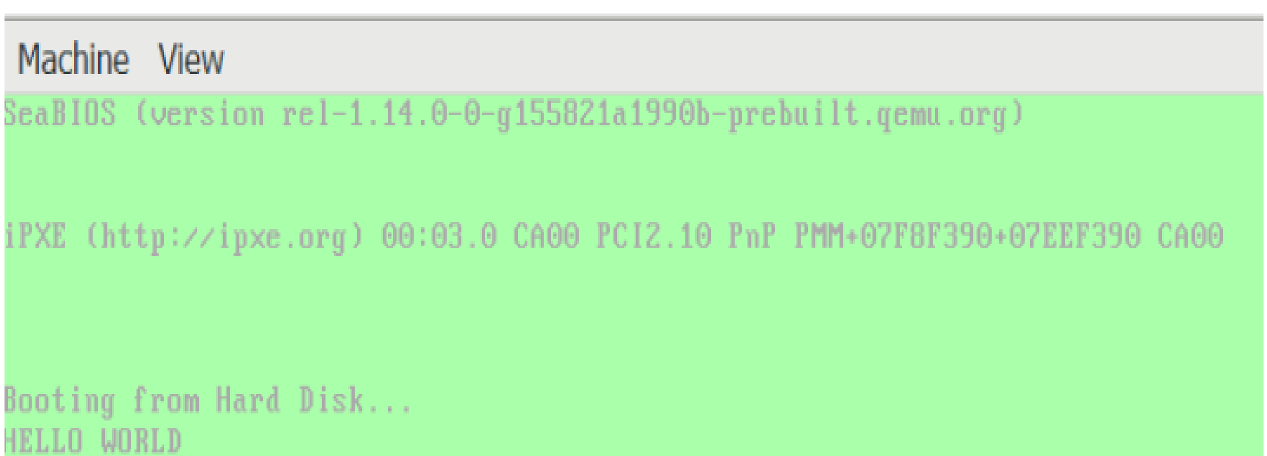


- **Filling the screen with colors:**

  To our hello world assembly code, we added the following piece of code to print a green color to the screen:

```
mov ah , 0x0b  ; by changing the value
mov bh , 0x0   ; assigned to b1
mov bl , 0xff  ; (0xff) we could change
int 0x10       ; the screen colors
```

  We obtained the output below:



❖ Switching to 32bits protected mode:

We switched to 32 bits mode to allow us to protect some memory locations (where the kernel of our OS is found) from user mode programs cause these programs could take control of CPU and our OS would have no control anymore. To perform this switch we used a ready-made Global Descriptor Table(GDT) which is a special data structure which the processor directly validates. After defining and loading the GDT we could now switch to 32 bit mode. We had no special output(the same output as that of the boot sector above) since we only switched to 32 bit mode. The assembly code for our GDT and switch is given below:

```
;Switch To Protected Mode
cli ; Turns Interrupts off
lgdt [GDT_DESC] ; Loads Our GDT

mov eax , cr0
or  eax , 0x1
mov cr0 , eax ; Switch To Protected Mode

jmp  CODE_SEG:INIT_PM ; Jumps To Our 32 bit Code
;Forces the cpu to flush out contents in cache memory
```

```
GDT_BEGIN:

GDT_NULL_DESC:  ;The  Mandatory  Null  Descriptor
        dd 0x0
        dd 0x0

GDT_CODE_SEG:
        dw 0xffff              ;Limit
        dw 0x0                 ;Base
        db 0x0                 ;Base
        db 10011010b  ;Flags
        db 11001111b  ;Flags
        db 0x0                 ;Base

GDT_DATA_SEG:
        dw 0xffff              ;Limit
        dw 0x0                 ;Base
        db 0x0                 ;Base
        db 10010010b  ;Flags
        db 11001111b  ;Flags
        db 0x0                 ;Base

GDT_END:

GDT_DESC:
        dw GDT_END - GDT_BEGIN - 1
        dd GDT_BEGIN

CODE_SEG equ GDT_CODE_SEG - GDT_BEGIN
DATA_SEG equ GDT_DATA_SEG - GDT_BEGIN


times 510-($-$$) db 0
dw 0xaa55
```

❖ Making a boot loader:

A boot loader is a piece of code in Boot Sector which loads the remaining part of the OS to memory that is the C program will always be greater than 512 bytes. The piece of code we implemented is shown below:

```
;Boot Loader
mov bx , 0x1000 ; Memory offset to which kernel will be loaded
mov ah , 0x02   ; Bios Read Sector Function
mov al , 30     ; No. of sectors to read(If your kernel won't fit into 30 sectors
mov ch , 0x00   ; Select Cylinder 0 from harddisk
mov dh , 0x00   ; Select head 0 from hard disk
mov cl , 0x02   ; Start Reading from Second sector(Sector just after boot sector)

int 0x13        ; Bios Interrupt Relating to Disk functions
```

❖ Calling our C Kernel:

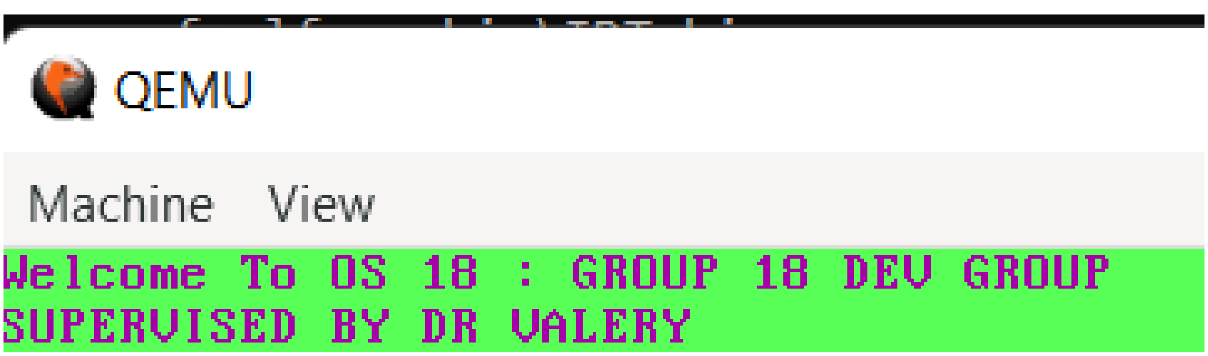
In order to execute the C program, we made, we used a linker to automatically calculate where our entry C function will be since we found it difficult to know where our entry C function is in memory since it changes as we modify our C program. Our linker here is kernel entry.asm and the code used by our linker is shown below:

```
START:
[bits 32]
[extern _start]
call _start
jmp $
```

```
int start(){
   char* video_memory = (char*) 0xb8000;
 *video_memory = 'K';
 }
```

Assembly program C program

From here we call our start function in our assembly program and obtained the below output:



we changed the K assigned to the video memory pointer to the text displayed on the output.

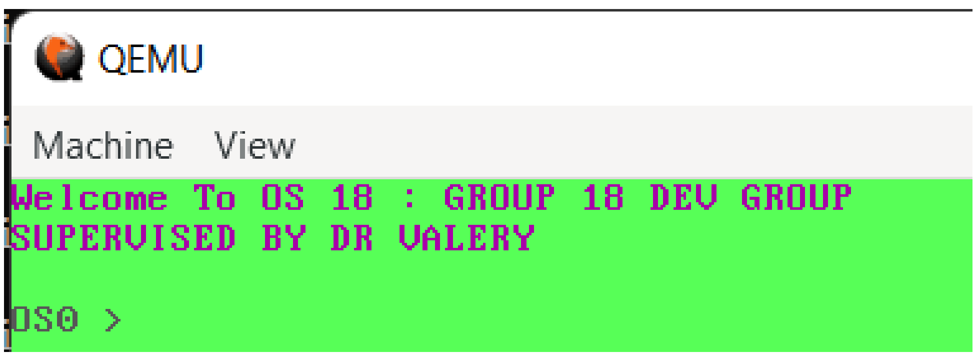
- **Video Graphics:**

  Displaying something was crucial part when developing our OS as we needed to print something to the screen to debug any issue arising. Normally after the boot up the computer video card will be in text mode, we could print something (characters and colors) to the screen the screen by poking (writing) memory location starting from 0xb800.

  Looking at the text mode video graphics it was hard for us to print strings to the screen so we implemented our own 'print' (print function) that we later called to do the printing operation.

  THEORY: Here we poked the video memory, as changing the data contained in the video memory continuously gives us a video feel since human eyes sees about 60 frames per second.

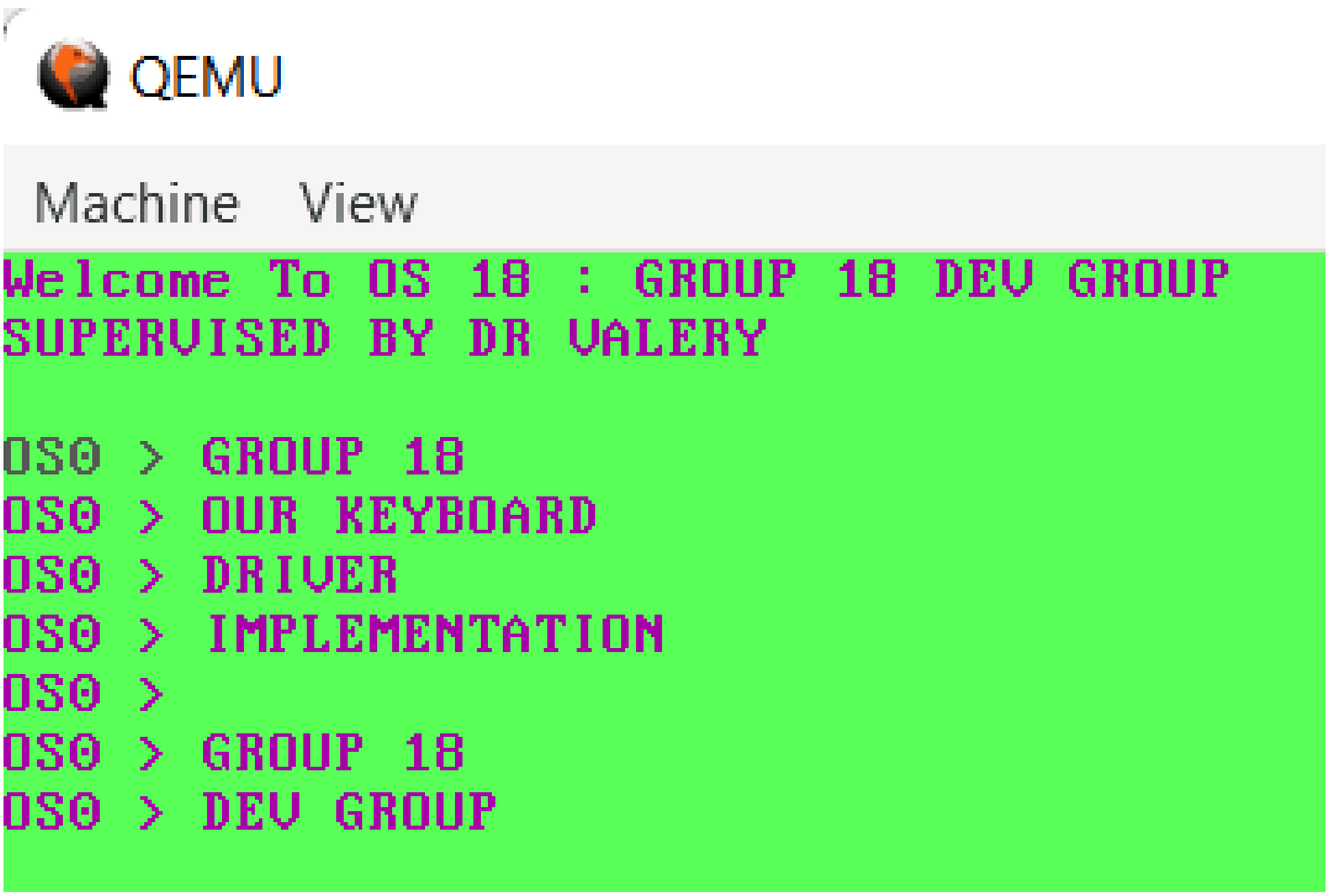
  our output for the video implementation is shown below:



- **Implementing keyboard driver:**

  Keyboard is the primary input device for the computer so working with the keyboard was an inevitable factor in the OS development. Our keyboard is slower than our processor hence it affects our processor speed Whenever a key is being pressed, the CPU will call a function that we pre define to it. The processor won't do the keyboard logic, but it will let us execute some code whenever a key is being pressed. We need to make some code to handle the keyboard input, and pass its address to the interrupt descriptor table and say to the processor to load it. After loading all the parameters and the location of our keyboard handling code, It will call that code whenever a key is being pressed. When we get this interrupt, We could try reading from the keyboard which gives us the key being pressed.

What keyboard gives as the value for pressed key is not ascii. It is named as scan codes. PIC or Programmable Interrupt Controller is a chip in the computer whose main job is to generate interrupts. When a key in keyboard is pressed, The Chip inside keyboard tells to the pic chip inside our computer to generate a #1 Interrupt. The pic chip will then decide the time to notify the CPU about the interrupt. When the CPU gets the message which says a key is being pressed, It executes a set of code which we told earlier to the CPU to execute when a key is pressed. After our implementation we entered some instructions and obtained the following output:



After this successful implementation we were able to input characters using the keyboard

- **First prototype OS 18:**
  Here we implemented our first prototype ***OS 18*** which was a combination of what we have done so far. By entering a series of commands one could clear the screen, change the screen color, play videos and print a string to the screen. Here when a videos is played it can only be stopped by closing the Qemu software. The different commands use to perform the above listed

Operations are given below:

CLS: this command clears the entire screen content

COLORA: changes screen color to

COLORB: changes screen color to

COLORC: changes screen color to

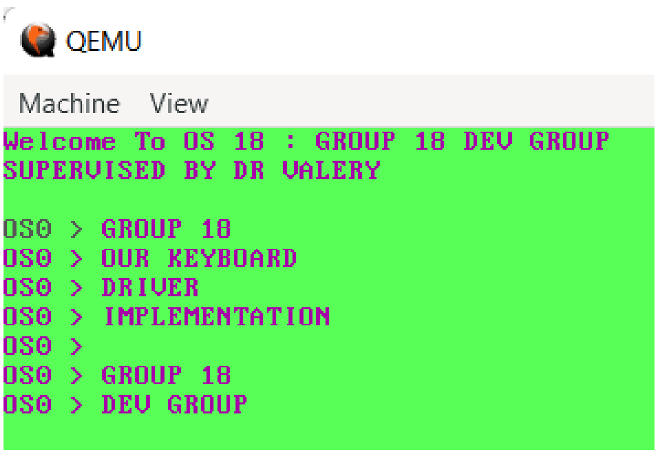
COLORDEF: changes screen color to definition color (green)

VID: plays video

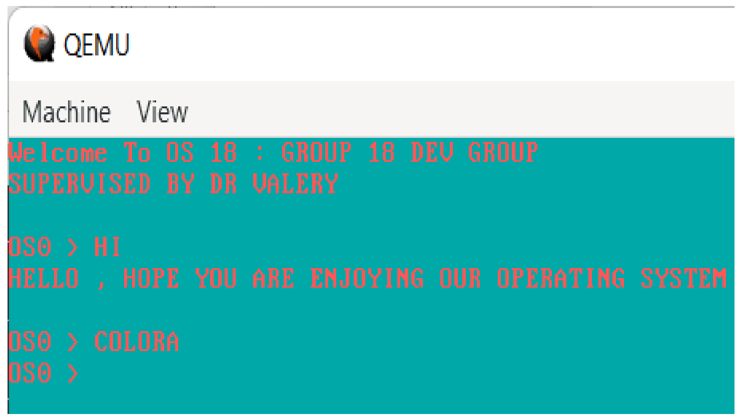
HI: displays a string

The output of the following commands is shown below:

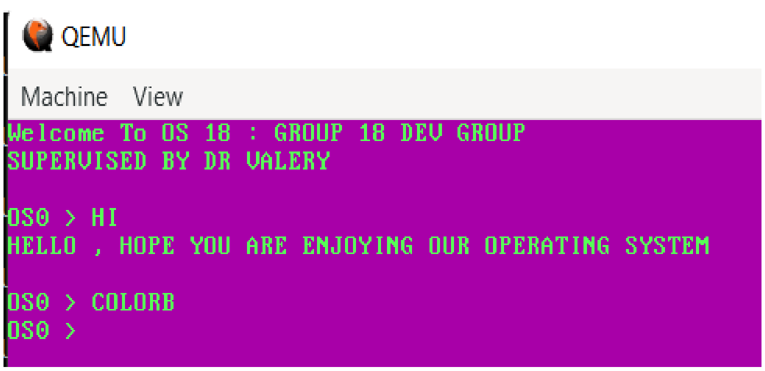
COLORDEF



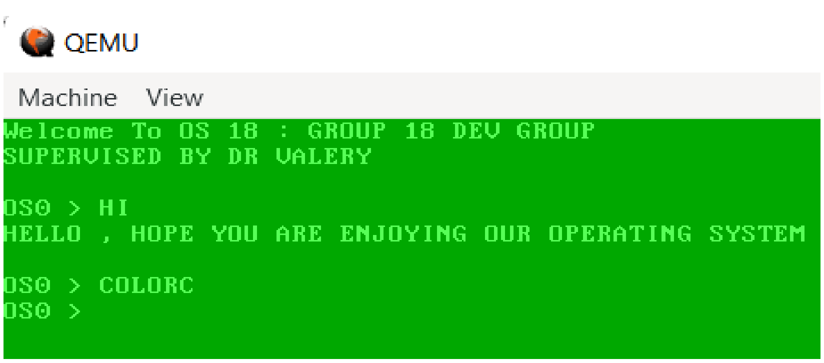
COLORA



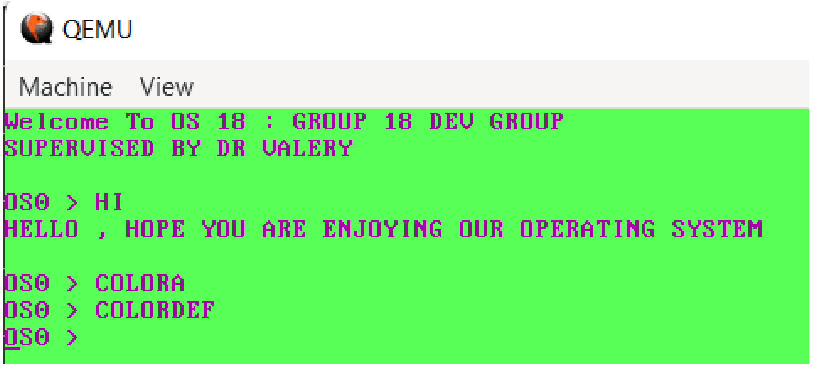
COLORB



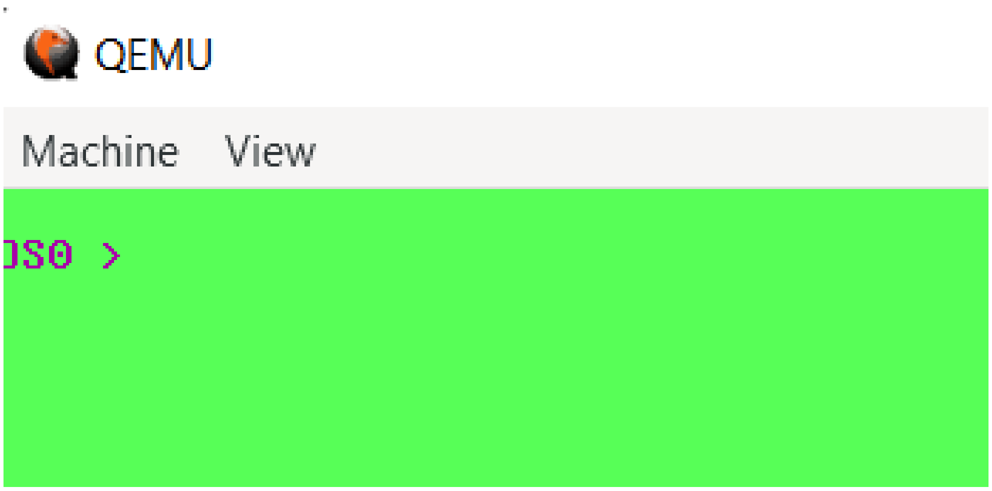
COLORC



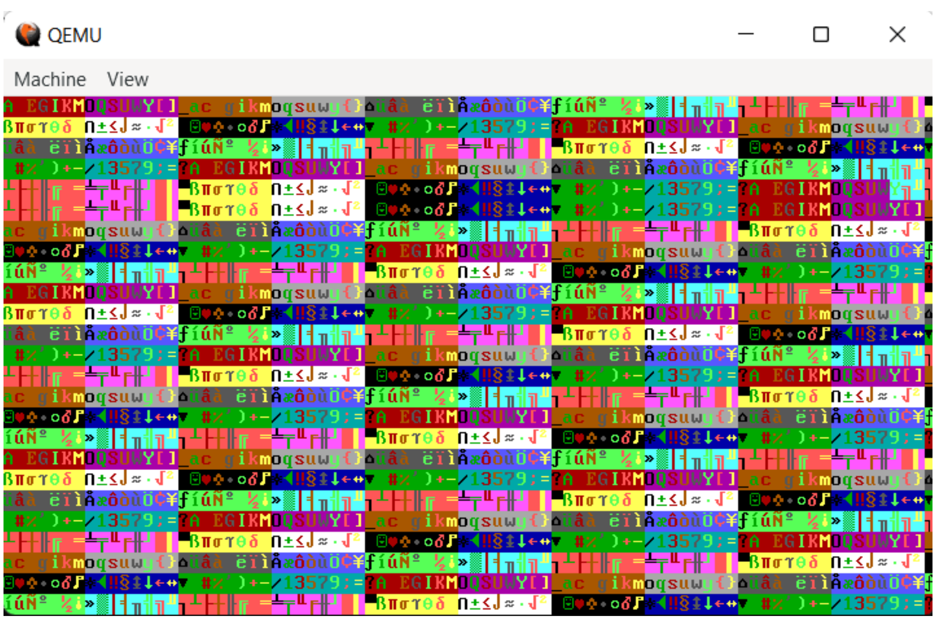
HI


QEMU
Machine View
Welcome To OS 18 : GROUP 18 DEV GROUP
SUPERVISED BY DR VALERY
OS0 > HI
HELLO , HOPE YOU ARE ENJOYING OUR OPERATING SYSTEM
OS0 > COLORA
OS0 > COLORDEF
OS0 >

CLS


QEMU
Machine View
OS0 >

VID

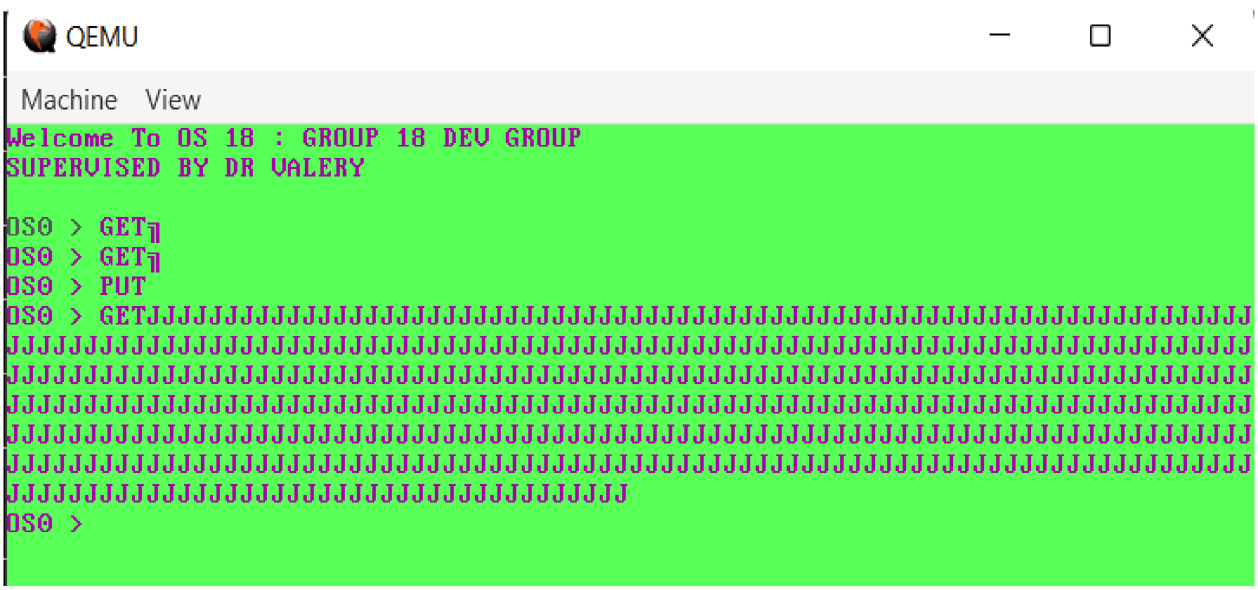

QEMU
Machine View

❖ Accessing hard disk

We implemented a Hard drive for the ATA technology. We Read/Wrote from the hard disk using LBA mode since we need to do is pass the Block address of sector. Passing 0 will give us access to the first sector (Boot sector).

We added two commands to the **strEval** function which GET and PUT commands. When the PUT command is typed on the QEMU, it first copies the number 0 to **blockAddr** and then proceeds to initialize every cell in at character array with 'J' and finally adds a null character. We set **J** as default character to check our implementation

If we try running the GET command first, we'll get some random character as output but if the PUT command is passed first then later on the GET command then we'll get a string of **J's**



❖ Creating a simple file

We'll build a file system which allows us to give names to a file and store up to 512-byte data in a file. Before creating a file in our OS, the user must format the hard disk using the FORMAT command. The formatting operation first stores four random bytes in the beginning of sector 0.

We should note that the sector 0 is always used to store the boot loader. Writing other data to sector 0 will make the system un-bootable. So we'll need to choose different Sectors.

FAT, NTFs, EXT, etc. are examples of file systems

a. **TO CREATE A FILE**

   We check the first four bytes stored in sector 0 and if it is same as what we stored in the formatting section, we do the next operation. Our main aim for this check is to see if we have previously formatted the disk. If the check fails, say to the user to enter the command to format it. Now we store the name of file in sector 0 just after the name of last file we created. Name of the very first file can be stored just after the first four bytes.

b. **TO SAVE A FILE**

   To save a file, we need to have created the file before. We shall use the SAVE command to do the save operation. After the user enters the save command, we obtain the index of the file specified. We will get 1 as index if the file specified is the first file defined at sector 0. Like that, we will get 2 as index if the file specified is the second file defined at sector 0. We then take this index as the sector count where the string should be saved to.

❖ GUI creation

Since we're to switch from text mode to graphics mode, we have different video modes to choose from. These different modes have its own abilities with its own supported resolution and colors. Graphics mode mostly deals with text mode graphics. Switching to graphics mode is done using BIOS but since we're in 32 bit protected mode we won't use BIOS on this mode. We'll switch down to 16bit mode.

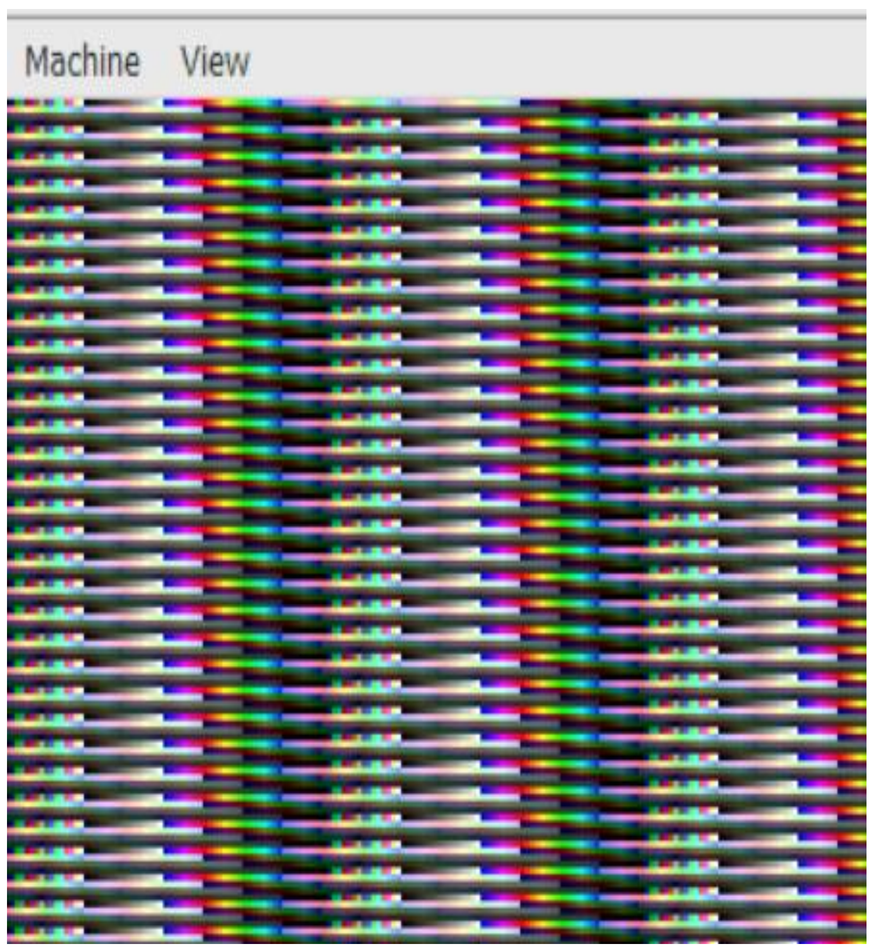
mov ah, 0x00; This option in BIOS is to switch mode

mov al, 0x13; This option switches to video mode, VGA320*200 256

int 0x10; With this function, we call the BIOS

We shall create a folder for this since our OS is in 32bit protected mode. The folder we'll create is just a crash file for the GUI. We've a whole lot of codes that we'll specify later on, for now we'll show our **main.c** file and the output generated when we include it in our **compile.bat** file.

```
int start () {
 char* vbuff = (char*) 0xA0000;
char colr = 0x00;
 int i = 0;
while (i < 320 * 200){
 *(vbuff + i) = colr;
 colr++;
 i++;
 }  }
```



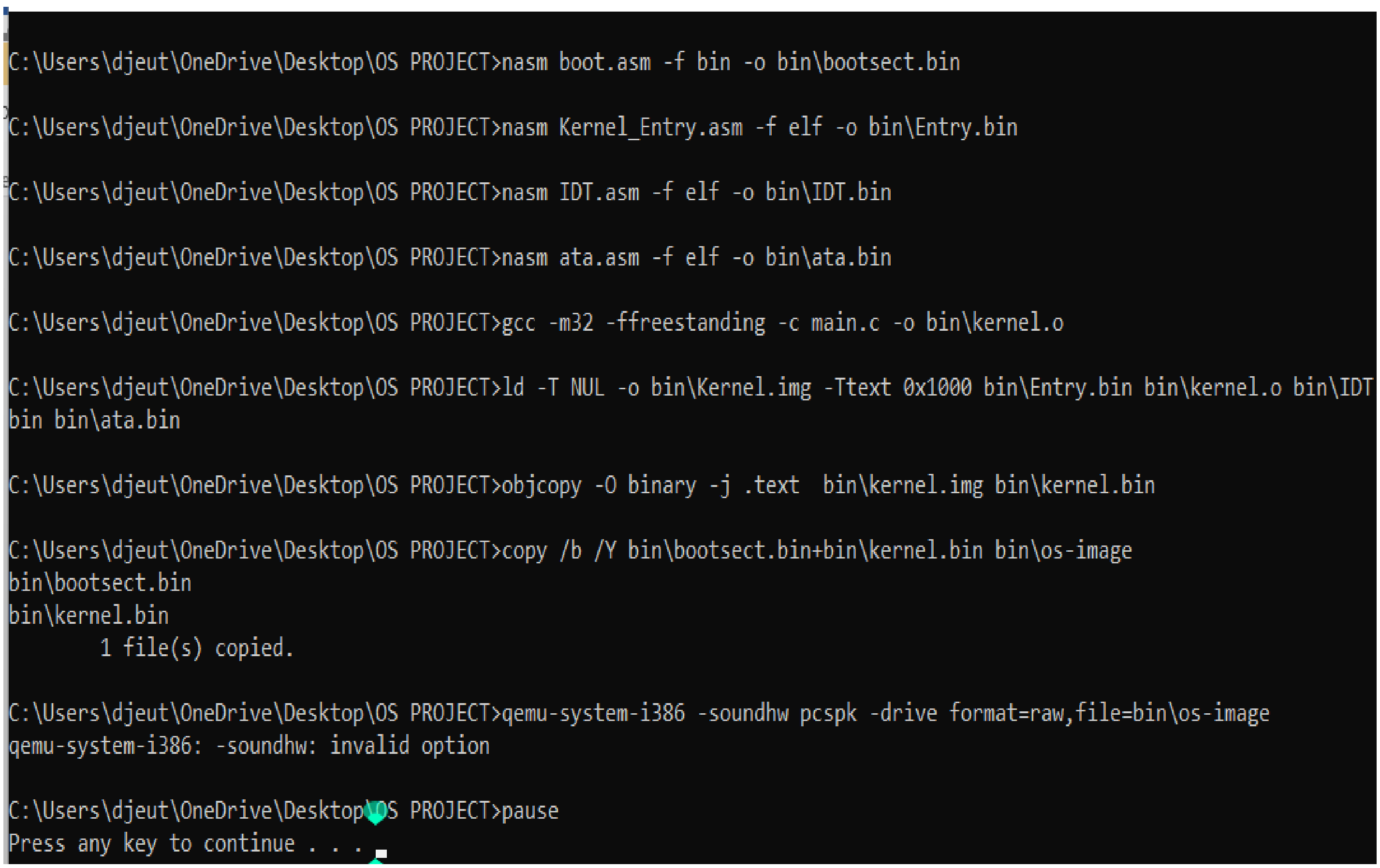
❖ **Implementing mouse driver**

We are to generate a PS2 mouse. A PS2 mouse generates IRQ12. Once we initialize a mouse, it sends 3 or 4 byte packets to communicate mouse movement, and mouse button press/release events. The PS2 mouse won't give us any special data to represent double clicks. The best way to check if a double click occur is by looking at the time difference between first and second click. If the time difference is less, then we threat is a double click.

We didn't have specific output for the MOUSE driver but we understood the code when implementing it.

❖ **Audio**

Generating Sound in our OS was a complicated which couldn't be resolved since the **qemu-system-i386 -soundhw pcspk -drive format=raw, file=bin\os-image** kept on displaing errors about the sound pack.



```
C:\Users\djeut\OneDrive\Desktop\OS PROJECT>nasm boot.asm -f bin -o bin\bootsect.bin

C:\Users\djeut\OneDrive\Desktop\OS PROJECT>nasm Kernel_Entry.asm -f elf -o bin\Entry.bin

C:\Users\djeut\OneDrive\Desktop\OS PROJECT>nasm IDT.asm -f elf -o bin\IDT.bin

C:\Users\djeut\OneDrive\Desktop\OS PROJECT>nasm ata.asm -f elf -o bin\ata.bin

C:\Users\djeut\OneDrive\Desktop\OS PROJECT>gcc -m32 -ffreestanding -c main.c -o bin\kernel.o

C:\Users\djeut\OneDrive\Desktop\OS PROJECT>ld -T NUL -o bin\Kernel.img -Ttext 0x1000 bin\Entry.bin bin\kernel.o bin\IDT
bin bin\ata.bin

C:\Users\djeut\OneDrive\Desktop\OS PROJECT>objcopy -O binary -j .text  bin\kernel.img bin\kernel.bin

C:\Users\djeut\OneDrive\Desktop\OS PROJECT>copy /b /Y bin\bootsect.bin+bin\kernel.bin bin\os-image
bin\bootsect.bin
bin\kernel.bin
        1 file(s) copied.

C:\Users\djeut\OneDrive\Desktop\OS PROJECT>qemu-system-i386 -soundhw pcspk -drive format=raw,file=bin\os-image
qemu-system-i386: -soundhw: invalid option

C:\Users\djeut\OneDrive\Desktop\OS PROJECT>pause
Press any key to continue . . .
```

Here we've an overview of the problem faced when running the sound pack. To get back to our normal command line we just need to remove the **-soundhw pcspk** which is normally there to get a sound.

CONCLUSION

Though the numerous difficulties encountered like the AUDIO and FILE SYSTEM, we succeeded implementing the basic parts of our operating system.