# BOS Programmers Guide

## Background

BOS is a very lean and bare bones, so much so, the language used to program the OS is x86 assembler. Although some may feal that assembler is complex, intimidating, and takes too long. I have found in my experience in creating BOS using assembler that after an initial learning curve, it is really not that hard to grasp. The main advantage of using assembler is that all the power and efficiencies of assembler are at your disposal.

You have the ability to create anything you want, without the need for anyone else's libraries or learning someone else's syntax. You have complete control and you can create whatever you want (Flynn).

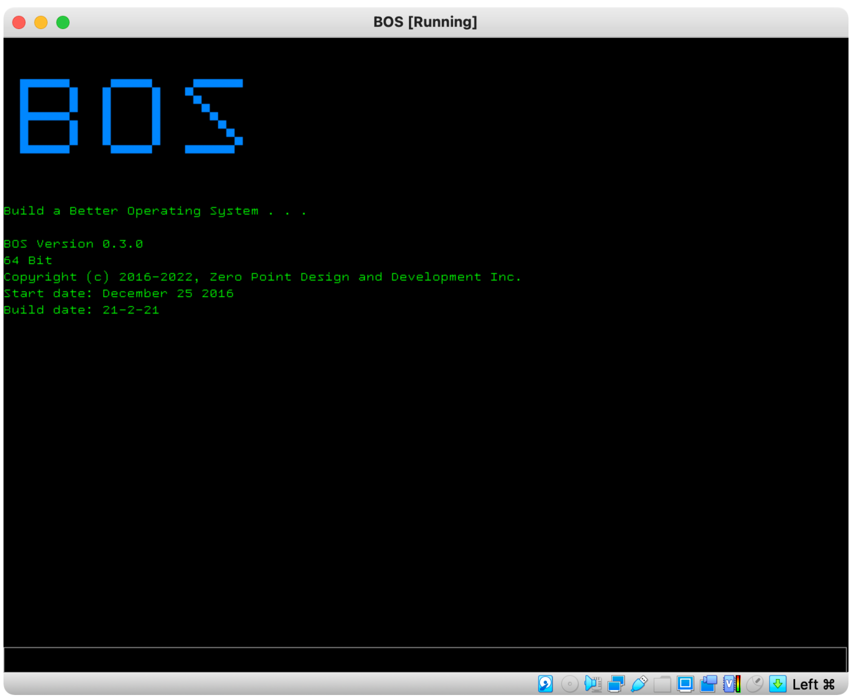



*Figure 1 - BOS*

## Setup

BOS is written in x86 assembler using Netwide Assembler (https://www.nasm.us/), a text editor that highlights assembler syntax, and a popular Linux distribution based on Ubuntu. For you to write code for BOS I would suggest the following (however, you can choose whatever tools you wish);

1. A Linux distribution - Lubuntu. I use a Ubuntu based distro.
2. A text editor - Atom.
3. An Assembler - nasm (sudo apt install nasm).
4. And the VM VirtualBox Expansion Pack. This is needed when you want to enable debugging in VirtualBox.

## Assembling Code

Anyone that has coded in assembler knows that code is not compiled, it is assembled (hence the name) and converted to machine code (numbers the CPU understands). The basic command to assemble your code is the following:

```
nasm <source_file> -f bin -l <source_file.lst> -o <output_file>

Example:
nasm hello_world.asm -f bin -l hello_world.lst -o hello_world.app
```

Where:

- <source_file> is the text file to be assembled.
- -f bin is the file format. BOS uses a simple flat binary file (keep it simple).
- -l <source_file.lst> generates a list file that will show the memory addressing, machine code and source code. This is needed to debug your code.
- -o <output_file> is the binary file itself. You can view this file using a hex editor (e.g. hd hello_world.app).

To make assembling more efficient, I would recommend creating a script file to assemble your code and naming the script file something very easy (e.g. ab). Below is a sample script you could use:

```
#!/bin/bash
# Script file to assemble the hello world program.
NAME="hello_world"
nasm $NAME.asm -f bin -l $NAME.lst -o $NAME.app
```

NOTE: Make sure the script file has execution permissions:

```
chmod +x ab.sh
```

## Source Code

BOS uses flat binary files to run applications; this file type was chosen because it left full flexibility to the developer. That is, format the file however you like and use it. For example, looking for certain values as inputs, looking for values at specific memory offsets (much like headers in an ELF file), etc.

There are a few rules that need to be followed in the source code:

1. All source code must begin with:
   ```
   org 0x70000000
   bits 64
   jmp ENTRY
   nop
   nop
   ```
2. User programs must begin at address 0x70000000, otherwise the program will generate a memory protection fault.
3. BOS is a 64 bit operating system, therefore the source file must use the ‘bits 64’ directive.
4. Jump to the first executable instruction. This is actually more of a recommendation then it is a rule. Using a jump statement (jmp) allows the developer to have any data they wish at the top of the file. If you don’t have a jump statement, whatever is after ‘bits 64’ will be treated as executable machine code. This can lead to some very interesting outcomes which may or may not have the desired effect.
5. The ‘nop’ assembler statements are not required, I have use them to fill CPU prefetching.
6. A program must exit using the `Exit` routine in lib_app.asm or calling the exit system call:
   ```
   mov rdx,0x0
   int 0xFF
   ```

## Graphics

All user programs can access graphics memory at virtual address 0x40000000. This is by design to allow the developer to write directly to the graphics card.

## Copy Binary File to BOS

Once an assembled binary file is created, it needs to be copied to BOS' App directory (all user programs are placed in this directory). Having all user programs in one location is done so by design. This makes it very easy to determine which files you are aware of and which files you are not aware of.

Copying binary files to BOS is done by running a program on BOS that will allow you to use a browser to drag and drop your files into BOS:

1. Start the BOS VM.
2. At the BOS command box type 'run load_app.bin'. This launches a program that will allow you to connect with a browser. You will see something similar to the image below.

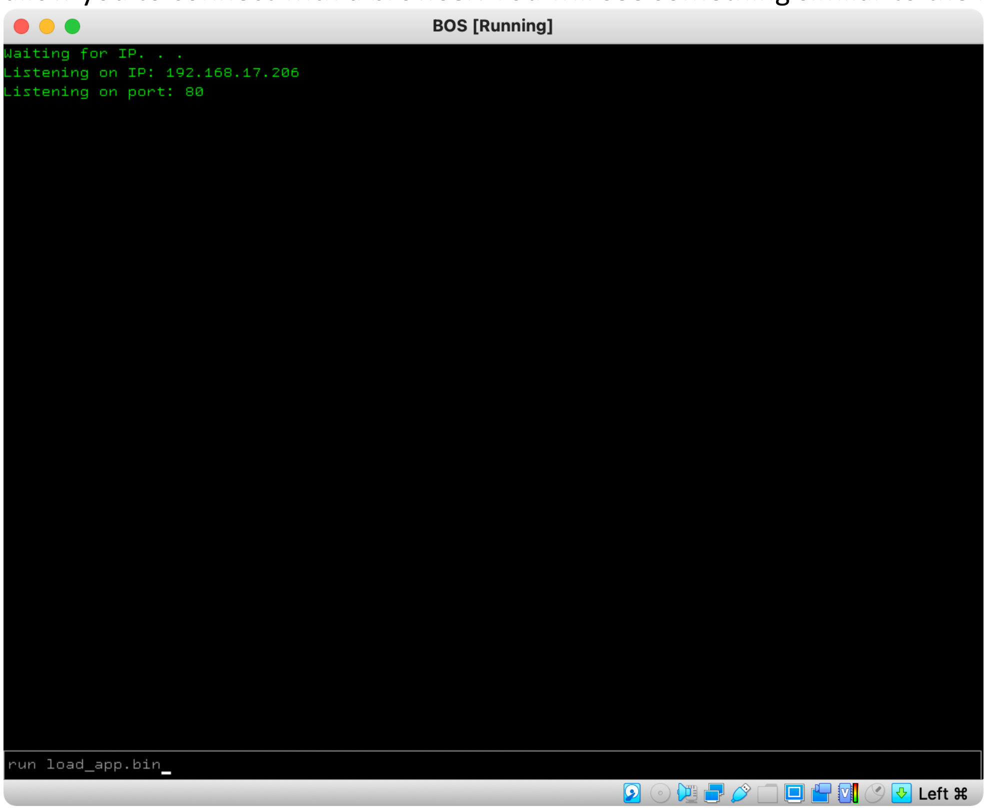



*Figure 2*

3. Referring to the 'Listening on IP' line in figure 2, make note of the IP address. This is the IP address you will put in the browser. If you happen to change the screen (e.g. clear), you can still get the IP address by typing the command 'ip show' and referring to the 'IP Address' line.

4. Launch a browser and type the IP address in the address bar. You should see something similar to figure 3.

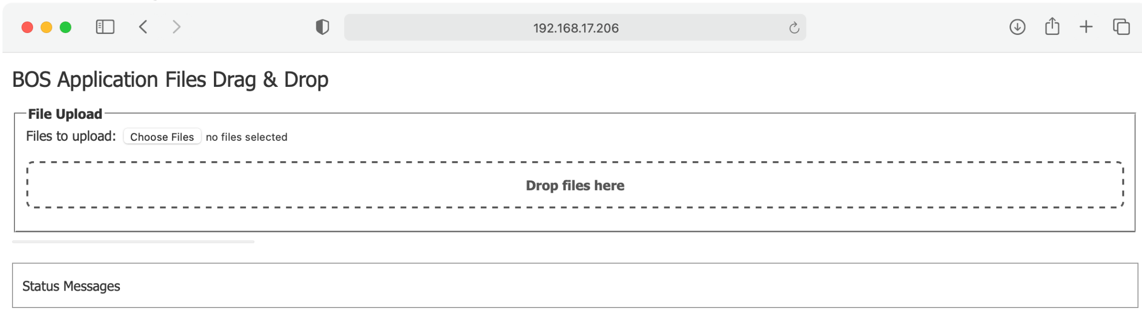



*Figure 3*

5. From a file window, drag the binary file to the 'Drag files here' box.

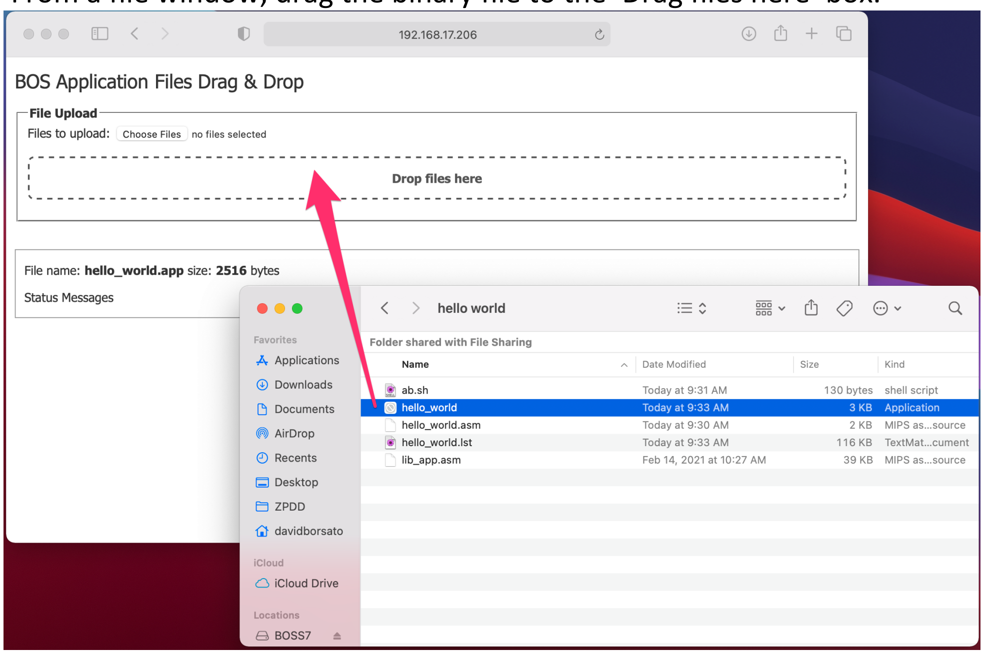
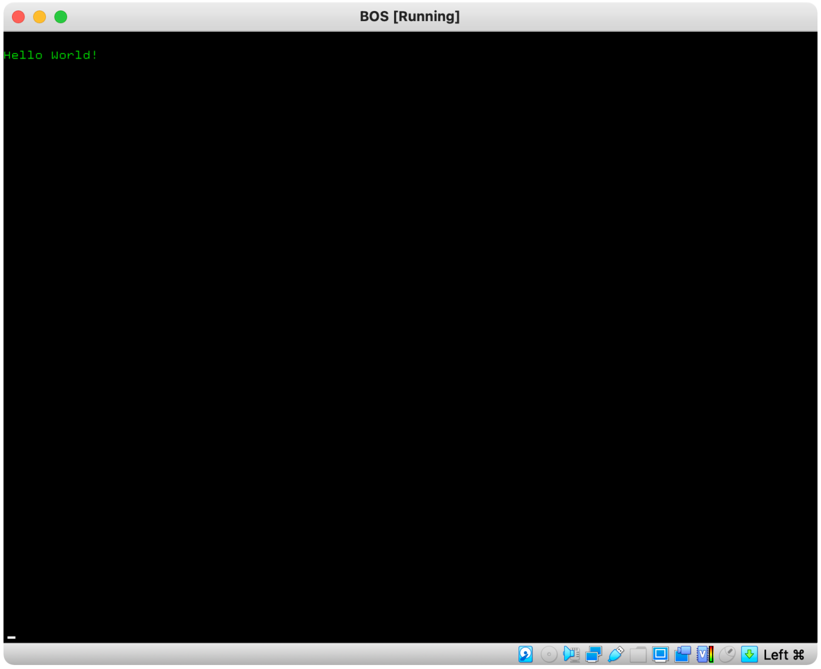



*Figure 4*

6. Go back to BOS.
7. To run the program type 'run <program_name>'. In this case the command would be 'run hello_world.app'.

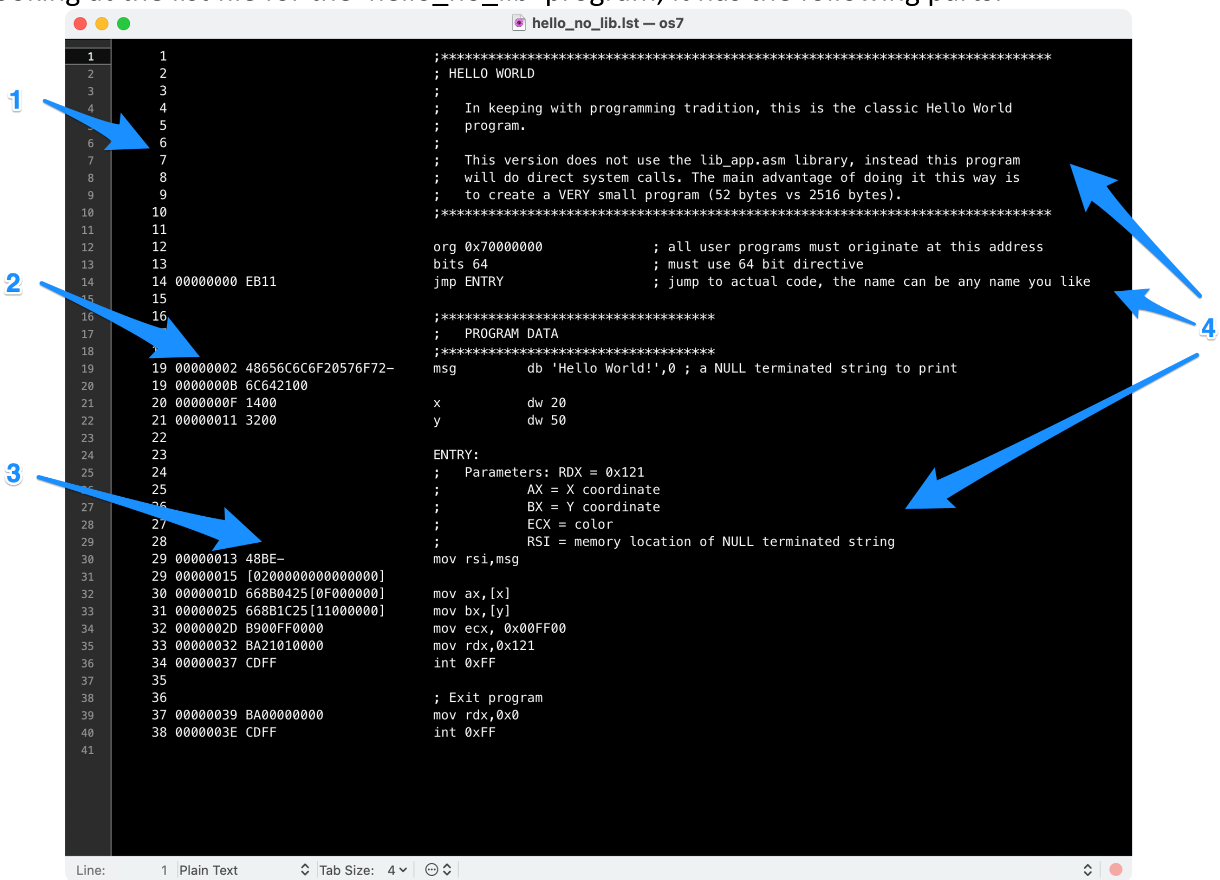



8. Done.

## Debugging Code

All developers need to be able to debug their code. One common way is to print information to the screen, which is still a good approach with BOS. The other way is to stop the virtual machine and inspect code, registers and memory directly using VirutalBox's debug mode. This mode will make use of the list file.

Looking at the list file for the 'hello_no_lib' program, it has the following parts:




```
 1                                      ;******************************************************************************
 2                                      ; HELLO WORLD
 3                                      ;
 4                                      ;   In keeping with programming tradition, this is the classic Hello World
 5                                      ;   program.
 6                                      ;
 7                                      ;   This version does not use the lib_app.asm library, instead this program
 8                                      ;   will do direct system calls. The main advantage of doing it this way is
 9                                      ;   to create a VERY small program (52 bytes vs 2516 bytes).
10                                      ;******************************************************************************
11
12                                      org 0x70000000              ; all user programs must originate at this address
13                                      bits 64                     ; must use 64 bit directive
14 00000000 EB11                        jmp ENTRY                   ; jump to actual code, the name can be any name you like
15
16                                      ;***********************************
17                                      ;   PROGRAM DATA
18                                      ;***********************************
19 00000002 48656C6C6F20576F72-         msg         db 'Hello World!',0 ; a NULL terminated string to print
19 0000000B 6C642100
20 0000000F 1400                        x           dw 20
21 00000011 3200                        y           dw 50
22
23                                      ENTRY:
24                                      ;   Parameters: RDX = 0x121
25                                      ;               AX = X coordinate
26                                      ;               BX = Y coordinate
27                                      ;               ECX = color
28                                      ;               RSI = memory location of NULL terminated string
29 00000013 48BE-                       mov rsi,msg
29 00000015 [0200000000000000]
30 0000001D 668B0425[0F000000]          mov ax,[x]
31 00000025 668B1C25[11000000]          mov bx,[y]
32 0000002D B900FF0000                  mov ecx, 0x00FF00
33 00000032 BA21010000                  mov rdx,0x121
34 00000037 CDFF                        int 0xFF
35
36                                      ; Exit program
37 00000039 BA00000000                  mov rdx,0x0
38 0000003E CDFF                        int 0xFF
```

*Figure 5*

1. Line numbers: Each line is numbered, not used.
2. Memory offset: This is important and will be discussed in more detail.
3. Machine code: Assembled code into actual machine code, not really used but still informative.
4. Source code: Source code itself, this is used to determine break points and helps when stepping through the code.

Using the information in the list file, we can use VirutalBox's debug mode to set a break point that will stop the OS. When the OS is stopped, you can now inspect the register's values and memory to determine if the program is doing what you expect.

The way a break point is set is by specifying a memory address to stop at. This is why the memory offset in the list file is important. Using the listing in figure 5, if we wanted to stop at the line:

```
mov rsi,msg
```

The memory address to stop at will be 0x70000013. This is determined by doing the following:

1. Using the source code (item 4), find the line you want to line at.
2. Get the memory offset value (item 2) and add it to 0x70000000. This is the virtual address for all user programs and cannot be changed.
3. Therefore, 0x70000000 + 0x13 = 0x70000013. Note this is a hex number.

If you wanted to stop at the line '`mov rdx,0x121`', the memory address to stop at would be 0x70000032. And so on.

Starting a VM in debug mode is different than normally starting a VM. Normally you would start a VM from the VirtualBox main screen by highlighting the VM and selecting 'Start', double clicking the VM, etc.

To start a VM with debugging enabled, this must be done at the command line. And, I have found this works best when you have VirtualBox running while you use the command line.

The command to start a VM in debug mode is:

```
VirtualBoxVM --debug-command-line --start-dbg --startvm <VM_NAME> &
```

For BOS use:

```
VirtualBoxVM --debug-command-line --start-dbg --startvm BOS &
```

The BOS VM will launch in a paused state. This gives you the ability to set break points before the OS runs. See figure 6.

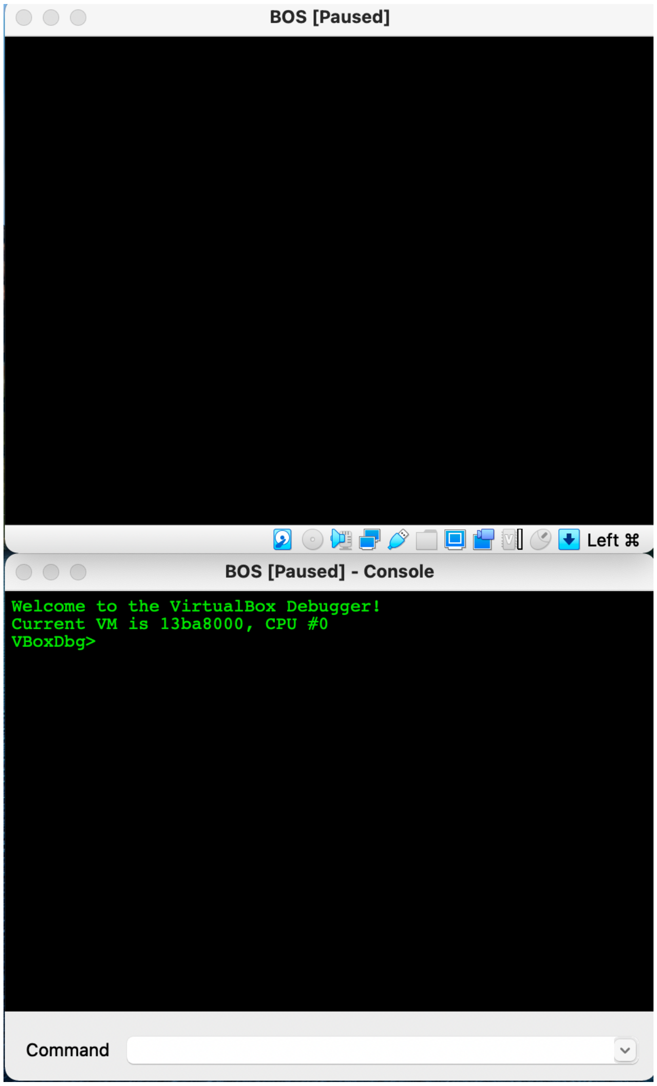


*Figure 6*

In the VirtualBox Console Command box, type this command to set a break point:
ba x 1 0x70000013

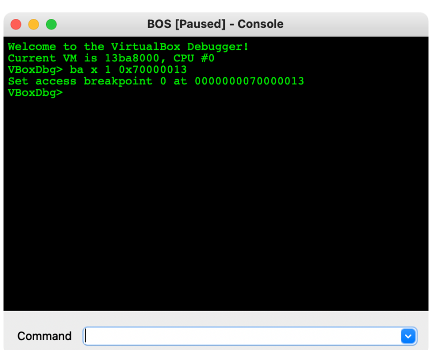


*Figure 7*

With the break point set, unpause the VM by selecting from the top menu Machine->Pause. Or Host+P on a MAC. BOS will startup as normal, the next step is to run the program:
`run hello_no_lib.app`

The program will now stop at the break point set earlier. Refer to the Console window in the figure below

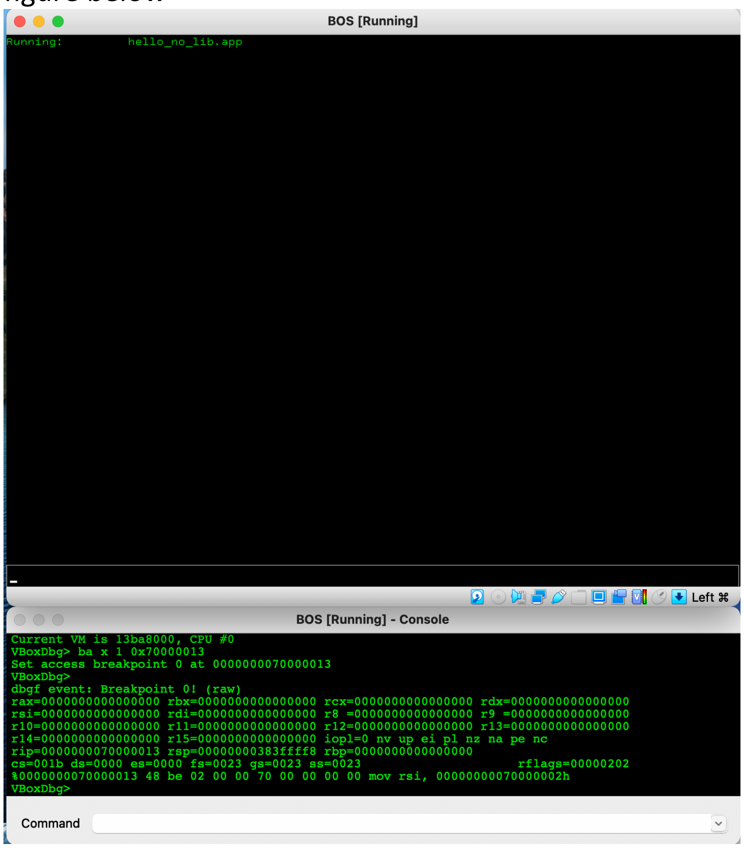



*Figure 8*

Figure 8 shows that in the Console window, the code has stopped and displays the value of the registers. At this point you can now issue commands to display memory, step through the code, etc.

Below are a common set up commands used:

```
ba x 1 <addr>       sets a break point at the address
bc <# | all>        deletes a breakpoint
bd <#>              disables a breakpoint
be <#>              enables a breakpoint
bl                  list break points

g              continue execution
p              step over
t              single step
t            [count] [cmds]            Trace .
tr                                     Toggle displaying registers for
tracing & stepping (no code executed).

ta           <addr> [count] [cmds]     Trace to the given address.
```

```
tc          [count] [cmds]                  Trace to the next call
instruction.
tt          [count] [cmds]                  Trace to the next return
instruction.

p           [count] [cmds]                  Step over.
pr                                          Toggle displaying registers for
tracing & stepping (no code executed).
pa          <addr> [count] [cmds]           Step to the given address.
pc          [count] [cmds]                  Step to the next call instruction.
pt          [count] [cmds]                  Step to the next return
instruction.


NOTE: use list file to find where to disassemble from
d              dump memory
dd             dump memory, double words (easier to read)
u 1028d7       unassembles code at 0x1028d7
u64            unassemble 64 bit code
r              show registers
```