

Cosmos OpenSSD Platform Tutorial

# Demo Guide

**ENC Lab. @ Hanyang University**

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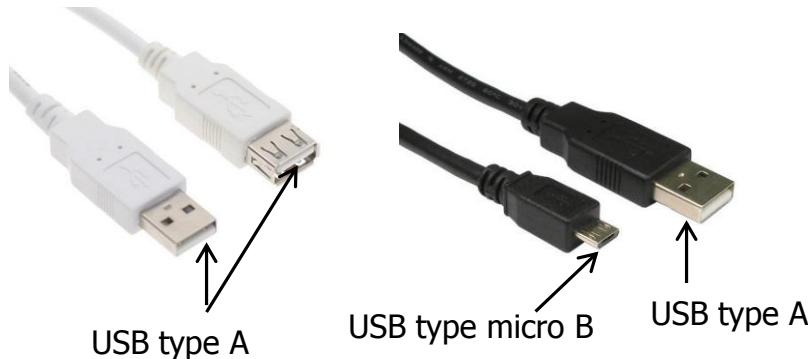
- 1. Cosmos OpenSSD Board Setting**
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- 4. Linux Device Driver Installation**

# Cosmos OpenSSD Board Setting

# Hardware Preparation

## ■ Hardware components

- Cosmos OpenSSD platform board
- External PCIe adapter
- External PCIe cable
- JTAG cable
  - USB type A to USB type micro B cable
  - Emulator, JTAG N pin cable (N: 7, 14, 20)
- USB type A to USB type A cable for UART



# Software Preparation

## ■ Software tools

- Xilinx ISE design suite 14.7 system edition
  - WebPACK is not allowed to use
- UART terminal emulator software
  - Xilinx Software Development Kit(SDK) includes UART terminal
  - You can use separate software such as Xshell

## ■ Software files: download from [OpenSSD project homepage](#)

- EDK project file
- Sources (C, RTL) / MCS file
- PCIe device driver
  - Linux: available
  - Windows: soon to be released

# FPGA Initialization Steps

**Step 1. Insert flash module into SO-DIMM**

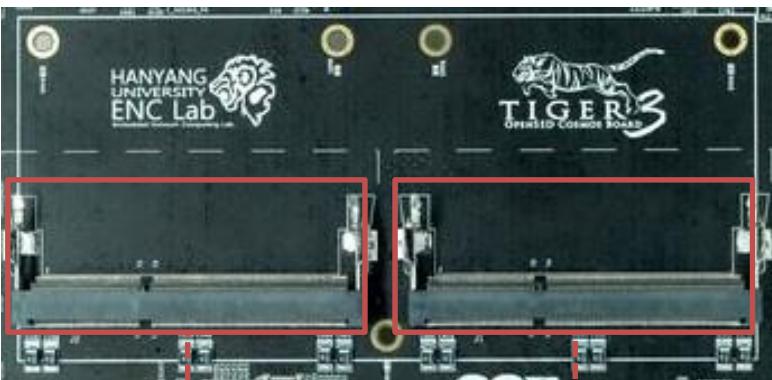
**Step 2. Set FPGA configuration mode**

**Step 3. Connect board with PC**

**Step 4. Check status related LEDs**

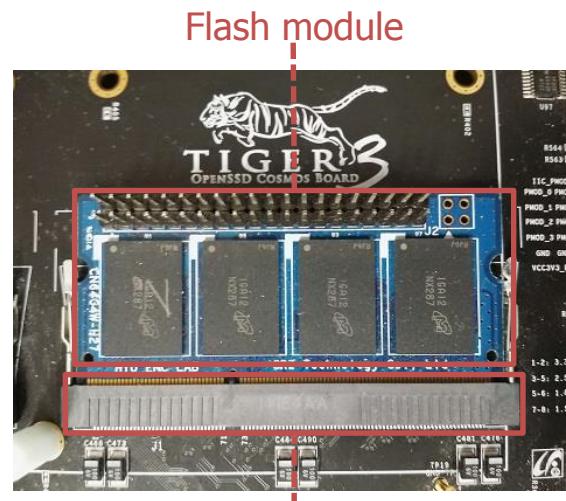
# Step 1. Insert Flash Module into SO-DIMM

- The released version of RTL code only supports J1
  - You can not use both yet



SO-DIMM (J2)

SO-DIMM (J1)



Flash module

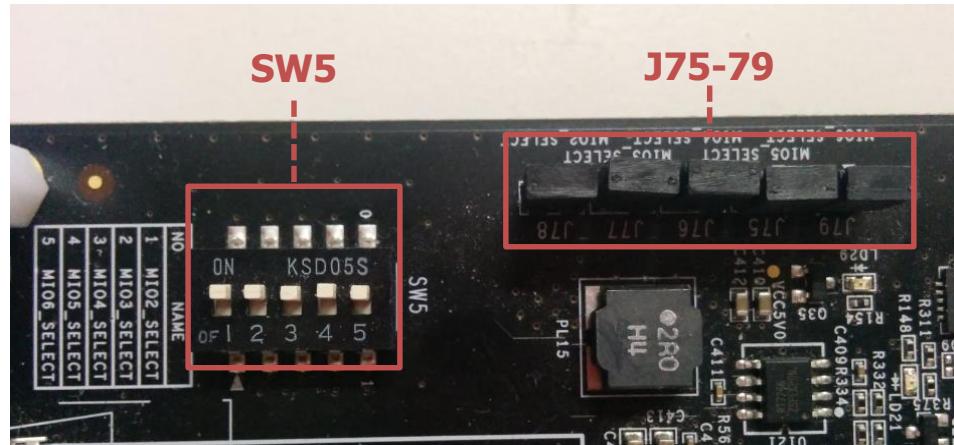
SO-DIMM (J1)

## Caution

- SO-DIMM has its own pin assignment (different from SDRAM)
- You should not insert any SDRAM module into this slot

# Step 2. Set FPGA Configuration Mode

- User can select how to configure the FPGA via the switch SW5



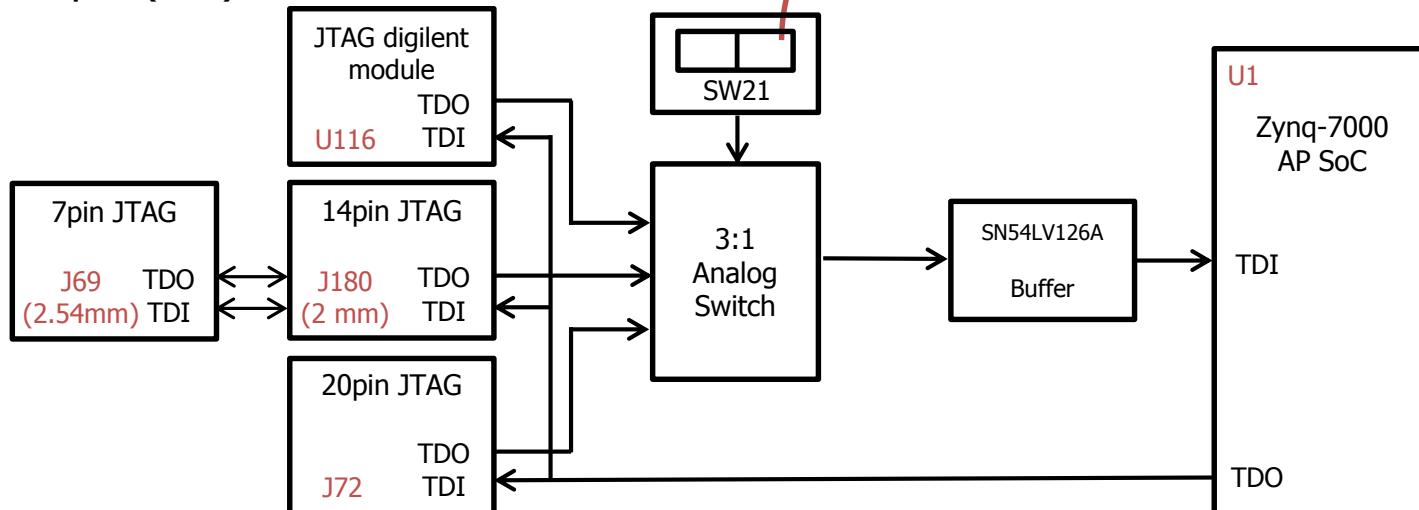
Mode	SW5					J75-79
	1	2	3	4	5	
JTAG	On	On	On	On	On	On
QSPI			On	Off		
SD card			Off	Off		

# JTAG Configuration Mode

- Download the configuration files to the platform board
  - Configuration files are generated by Xilinx ISE design suite
  - ELF file: software configuration file
  - BIT file: hardware programming file
  - BMM file: block memory map file
- Use may use one of three JTAG I/Fs
  - Digilent module (U116)
  - 14pin (J180)
  - 20pin (J72)

JTAG select SW (SW21) setting

Type	SW21	
	1	2
Digilent module	Off	On
14pin	Off	Off
20 pin	On	Off

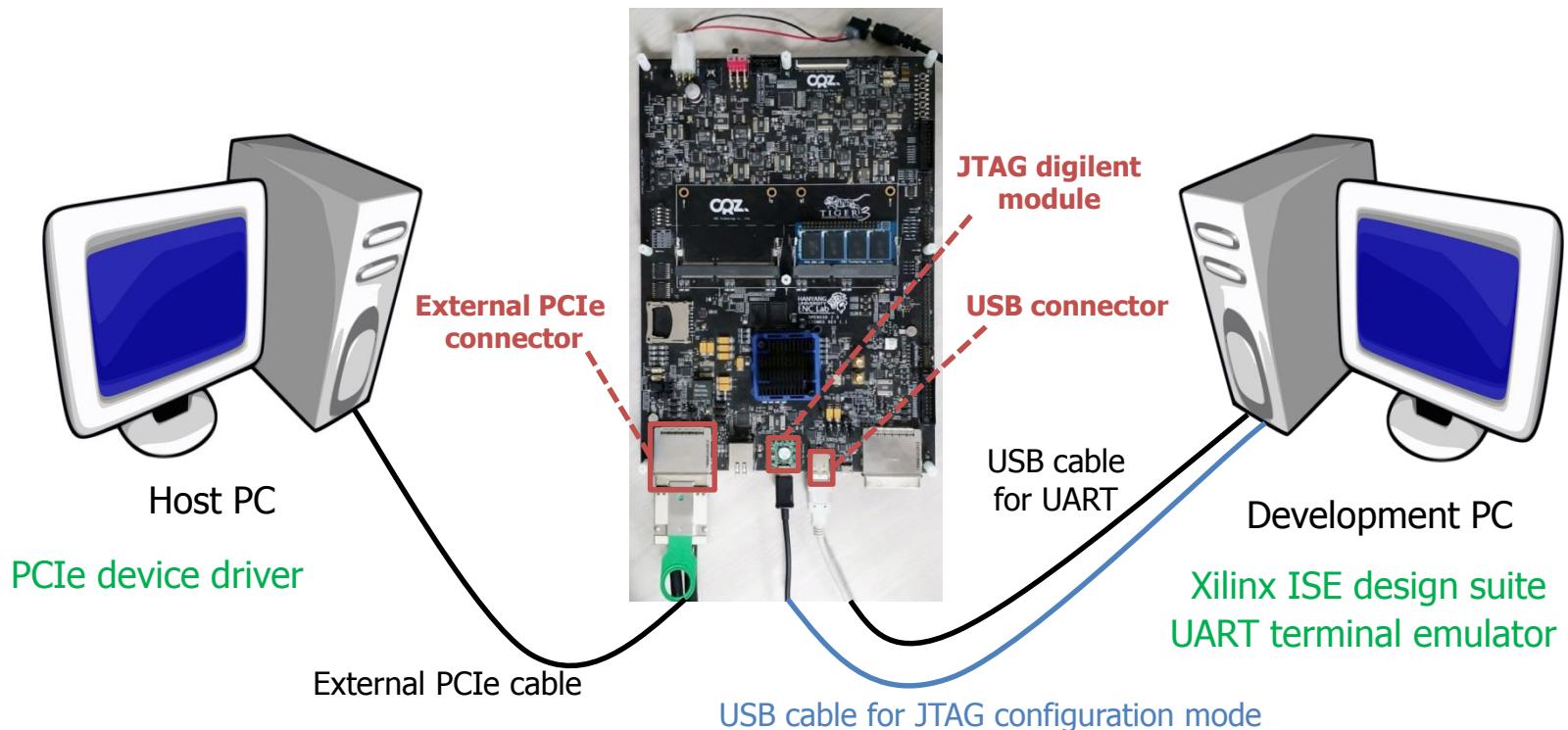


JTAG connection diagram

# Step3. Connect Board with PC

## Software preparation

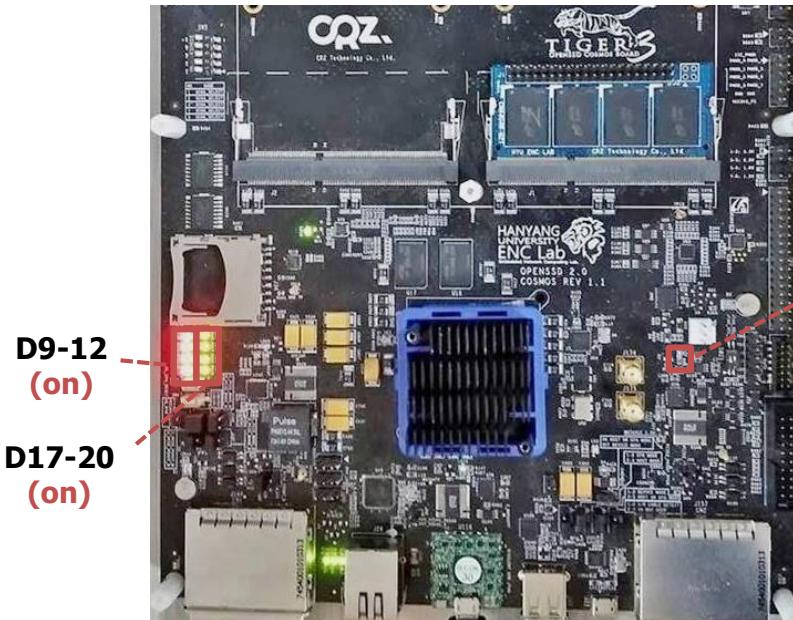
- Xilinx ISE design suite 14.7 system edition is installed on development PC
- UART terminal emulator software is installed on development PC
- PCIe device driver is installed on host PC



# Step 4. Check Status Related LEDs

LED	Description	Color	Before programing FPGA	After programing FPGA
LD1	FPGA initialization indicator	Green	Off	On
D9-12	User-configurable LEDs	Red	On	Off
D17-20		Green		

Note: FPGA has a pin called PUDC\_B which chooses either a pull-up mode or a pull-down mode on power-up.  
PUDC\_B is pre-set to pull-up mode



Before programing FPGA



After programing FPGA

# | Start with EDK

# Open EDK Project File

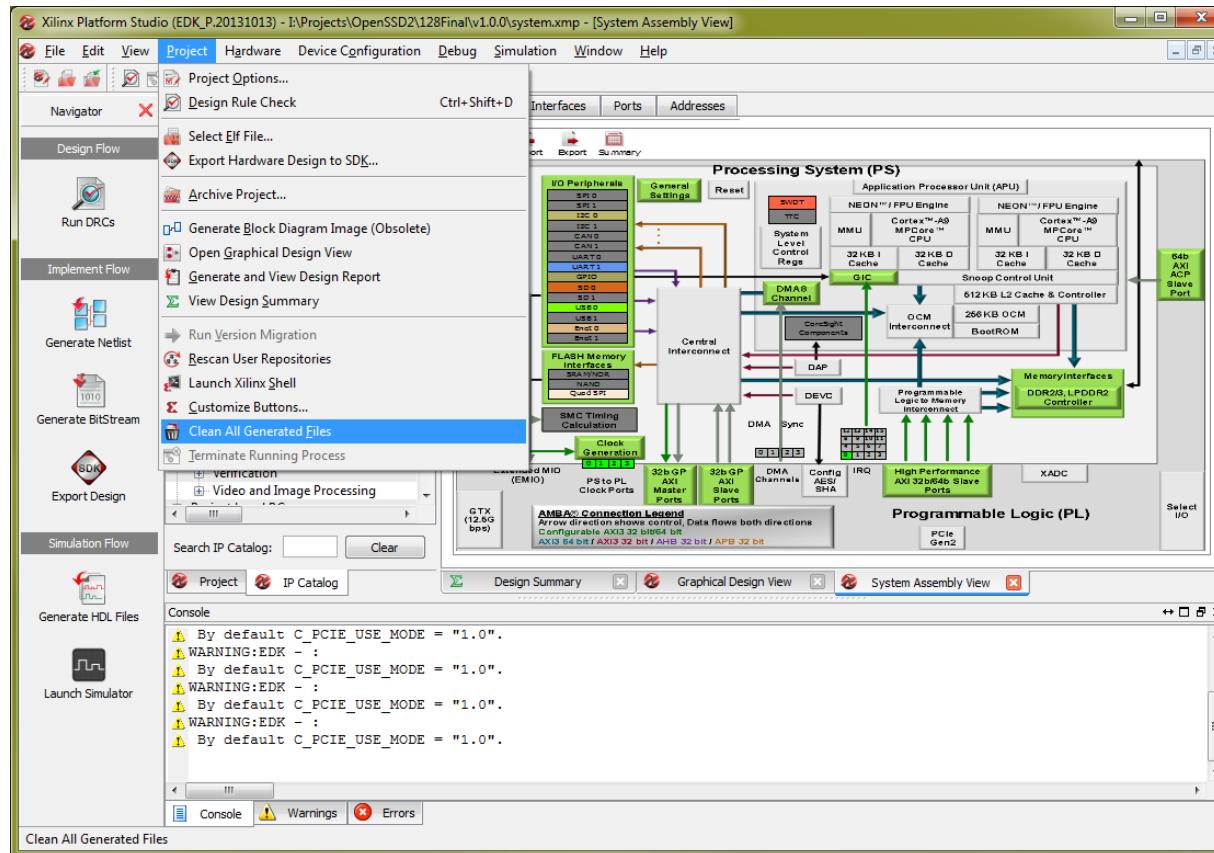
## ■ Open 'system.xmp' with Xilinx Platform Studio (XPS)

이름	수정한 날짜	유형	크기
data	2015-05-23 오후...	파일 폴더	
etc	2015-05-23 오후...	파일 폴더	
pcores	2015-05-23 오후...	파일 폴더	
system.bsb	2014-10-16 오전...	BSB 파일	2KB
system.make	2015-03-17 오후...	MAKE 파일	8KB
system.mhs	2015-03-11 오후...	MHS 파일	18KB
system.xmp	2015-03-11 오후...	Xilinx Platform St...	1KB
system_incl.make	2015-03-17 오후...	MAKE 파일	16KB

'system.xmp' in EDK project file

# Clean All Generated Files

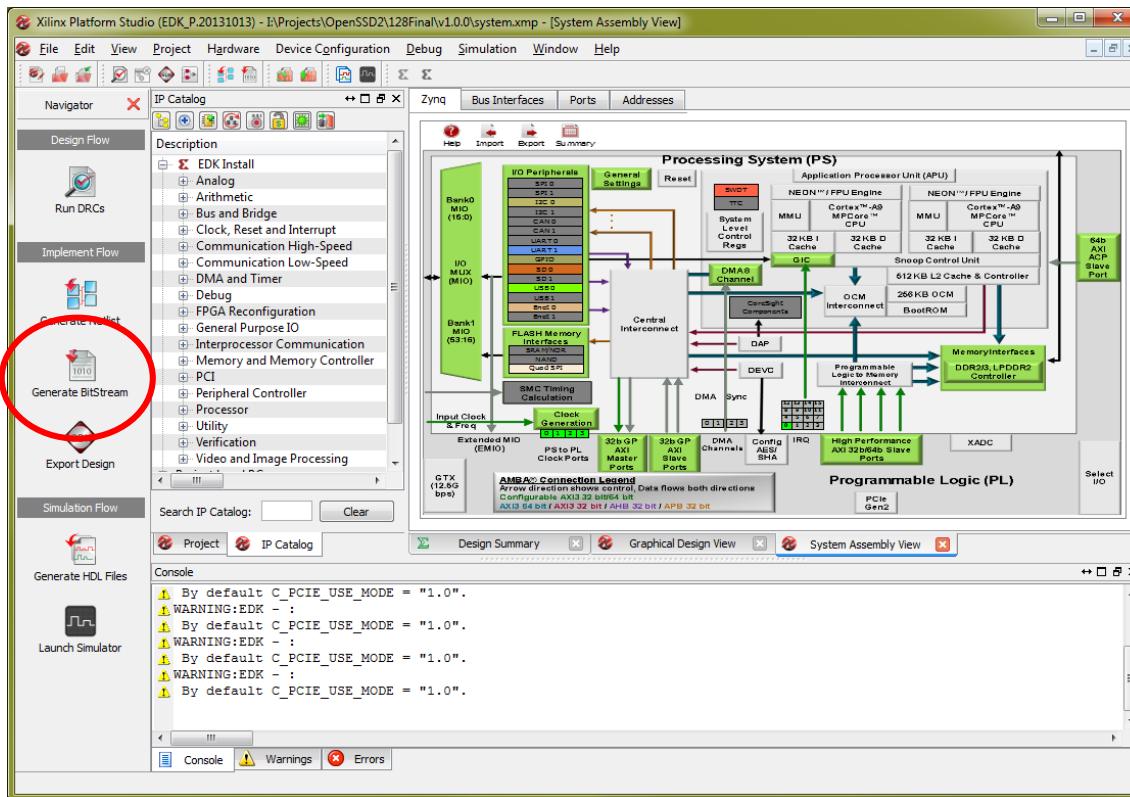
- Click 'Project' > 'Clean All Generated Files'



# Generate BitStream

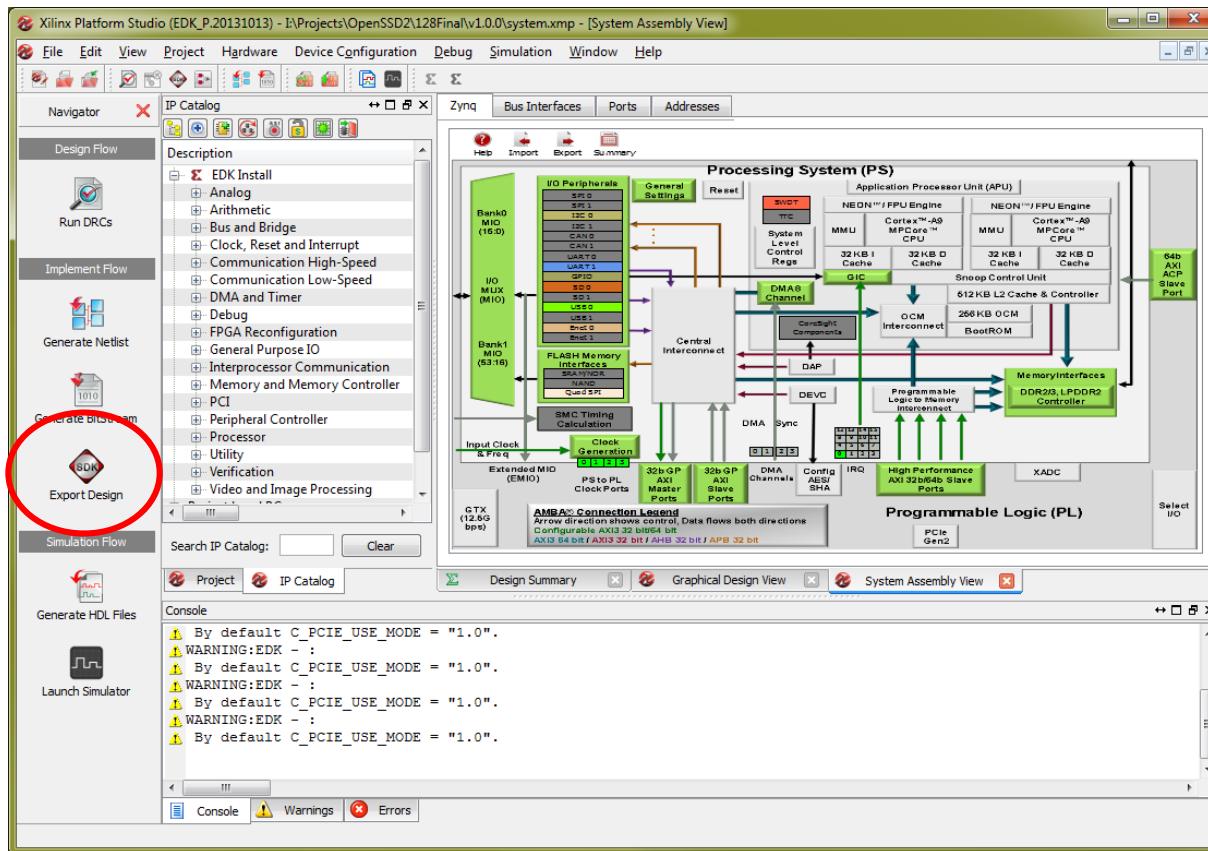
## Click 'Generate BitStream'

- XPS will generate the OpenSSD hardware bitstream
- Generating time will vary from 90 min to 150 min



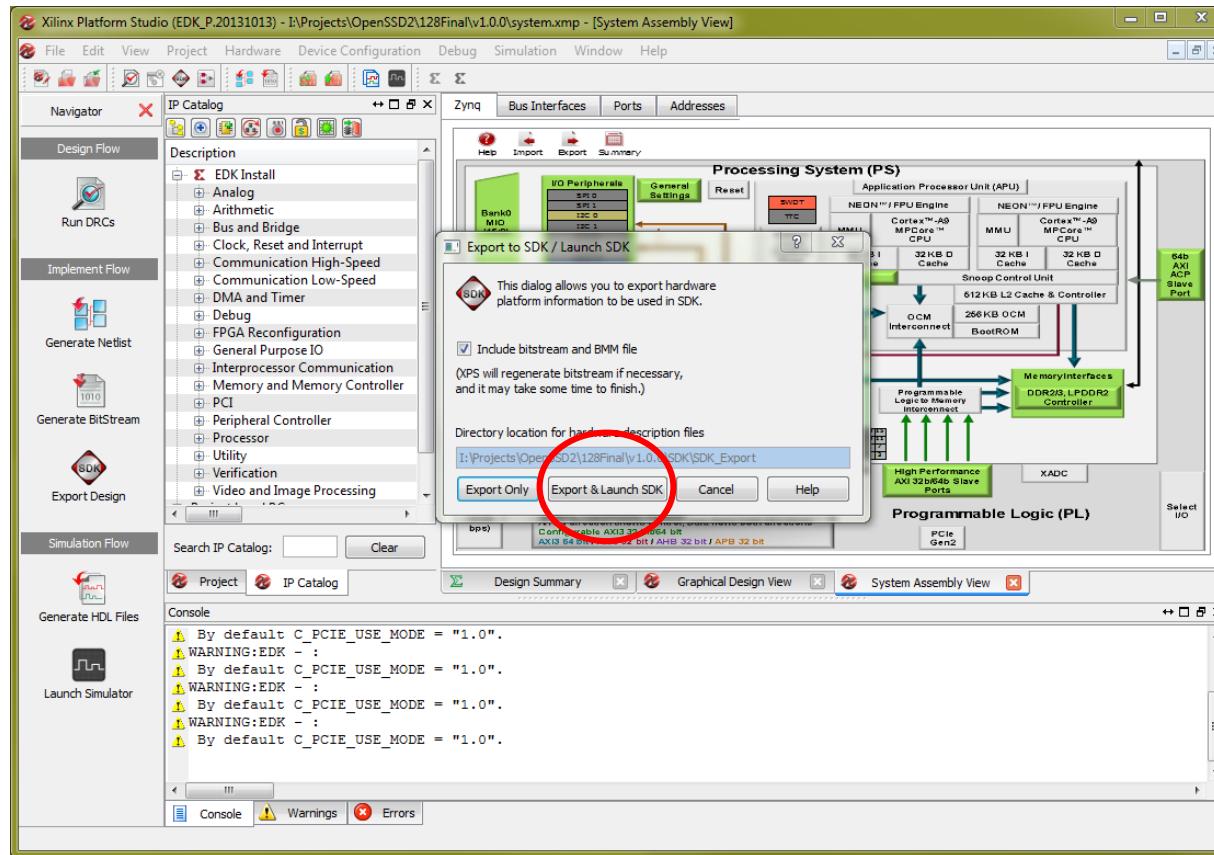
# Export the Hardware Design (1/2)

- Click 'Export Design'



# Export the Hardware Design (2/2)

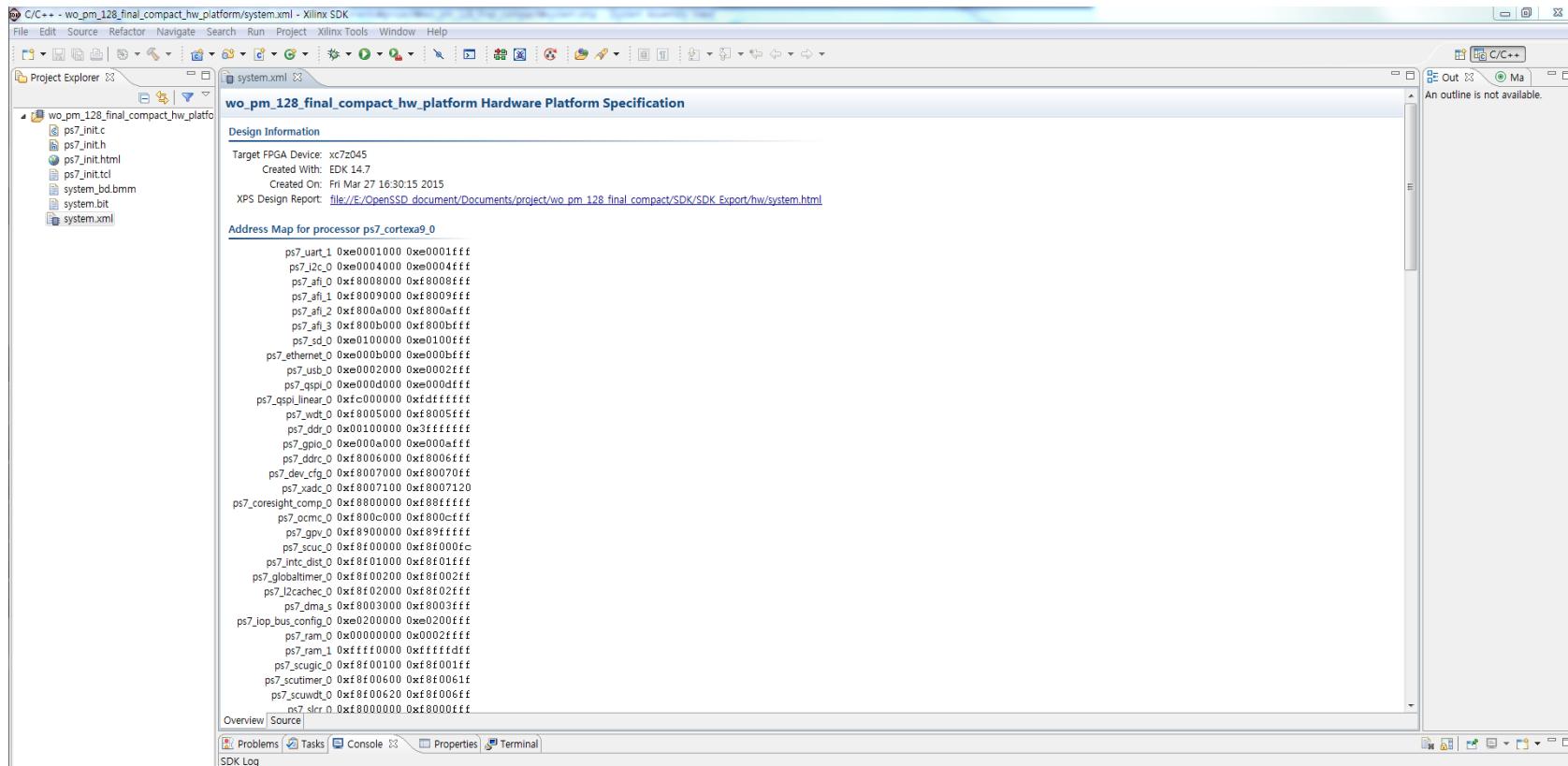
- Click 'Export & Launch SDK' when prompt box appears below



# | Start with SDK

# Initial State

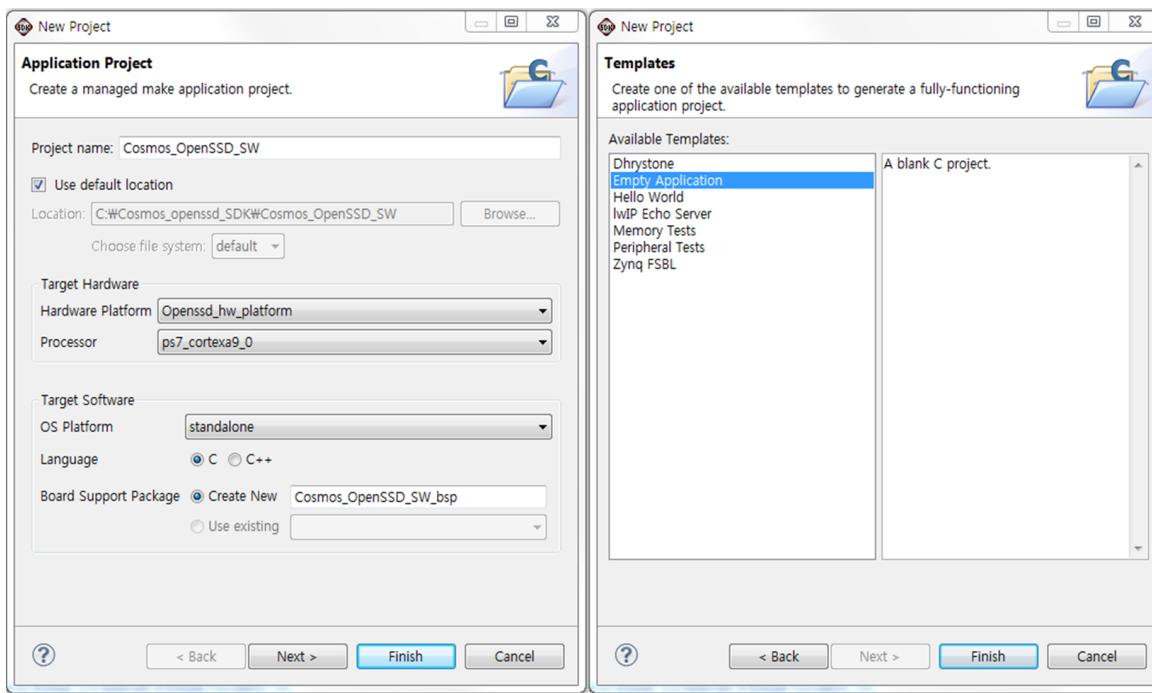
## EDK is exported to SDK



OpenSSD address map in SDK system.xml tab

# Make Application Project

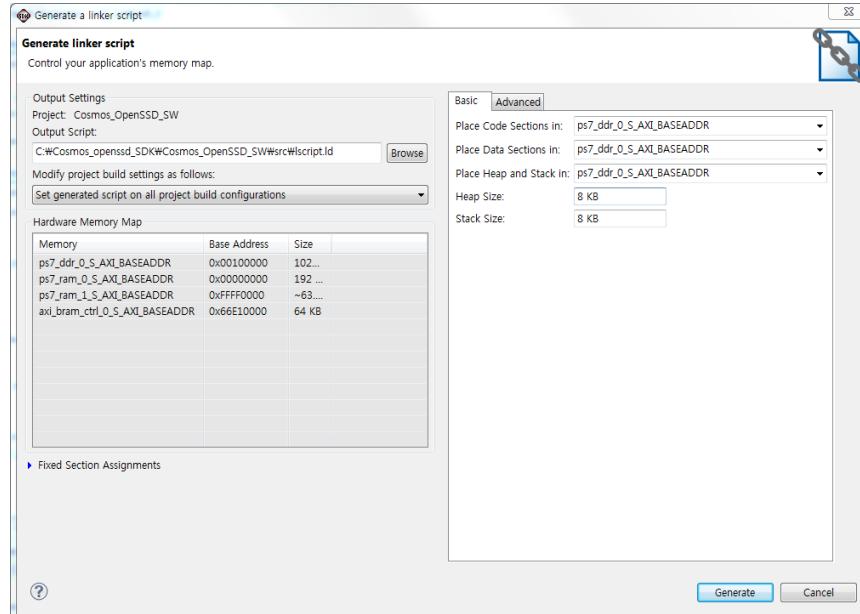
1. Select 'File' > 'New' > 'Application Project'
2. Type a 'Project name' and click 'Next'
3. Select 'Empty Application' in the template list and click 'Finish'



New project dialog box

# Import FTL into the Project

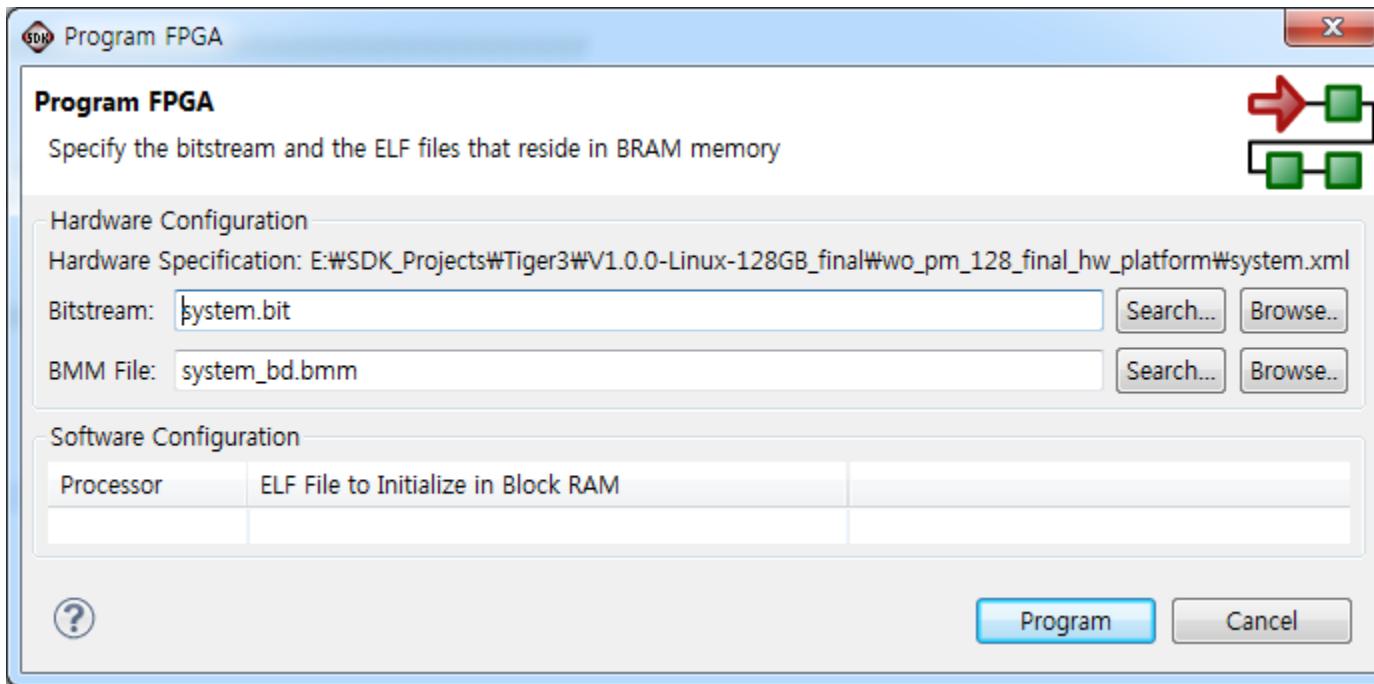
1. Import FTL into 'src' folder of the project
2. Right click the project folder and select 'Generate Linker Script'
3. Change the 'heap' and 'stack' size from 1 KB to 8 KB and click 'Generate'



Generate a linker Script dialog box

# Program FPGA

1. Set FPGA configuration mode as JTAG mode
2. Open 'Xilinx Tools' > 'Program FPGA' and click 'Program'
3. Connect UART terminal emulator software with baud rate 115200



Program FPGA dialog box

# Run FTL

1. Right click the project folder and select 'Run as' > '1 Launch on Hardware (GDB)'
2. UART messages will appear: "SSD firmware start"
3. Turn on the host PC
  - The host PC must be turned off before turning on
4. The UART terminal will show FTL initialization messages below

```
[ ssd NAND device reset complete. ]
[ ssd page map initialized. ]
:
[ ssd entire block erasure completed. ]
[ ssd block map initialized. ]
[ ssd die map initialized. ]
[ ssd gc map initialized. ]
[ Initialization is completed. ]
[ Initial bad block size: 92 MB. ]
[ User addressable storage size: 127 GB. ]
```

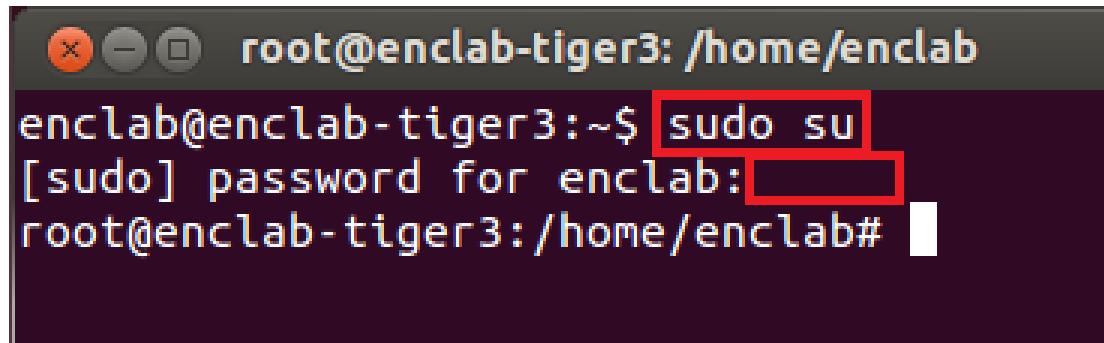
Example of FTL initialization messages

# Linux Device Driver Installation

\*Followings are done under Ubuntu 12.04.5 LTS and kernel 3.2.0-23-generic

# Compile Linux Device Driver (1/2)

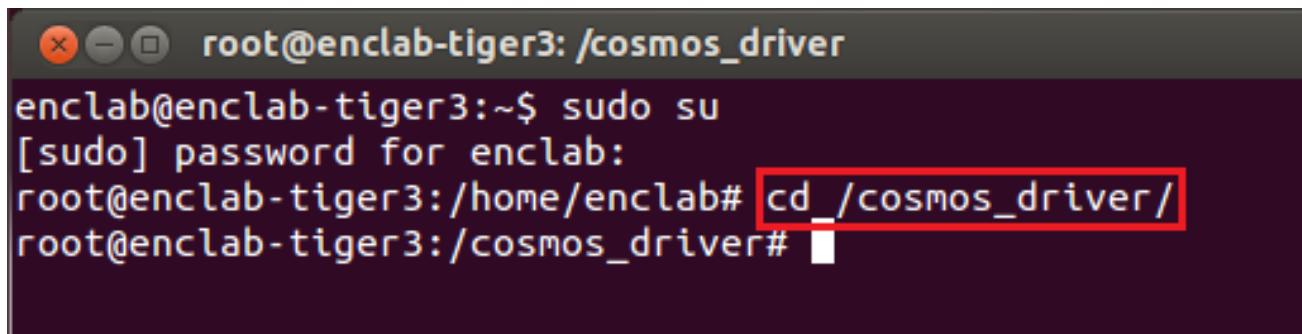
- Open terminal
- Type 'sudo su' and your password



```
root@enclab-tiger3: /home/enclab
enclab@enclab-tiger3:~$ sudo su
[sudo] password for enclab:
root@enclab-tiger3:/home/enclab#
```

A screenshot of a terminal window titled "root@enclab-tiger3: /home/enclab". The user has run the command "sudo su" and is prompted for a password. The password field is highlighted with a red rectangle. The terminal then shows the user is now root, with the prompt "root@enclab-tiger3:/home/enclab#".

- Go to the driver folder

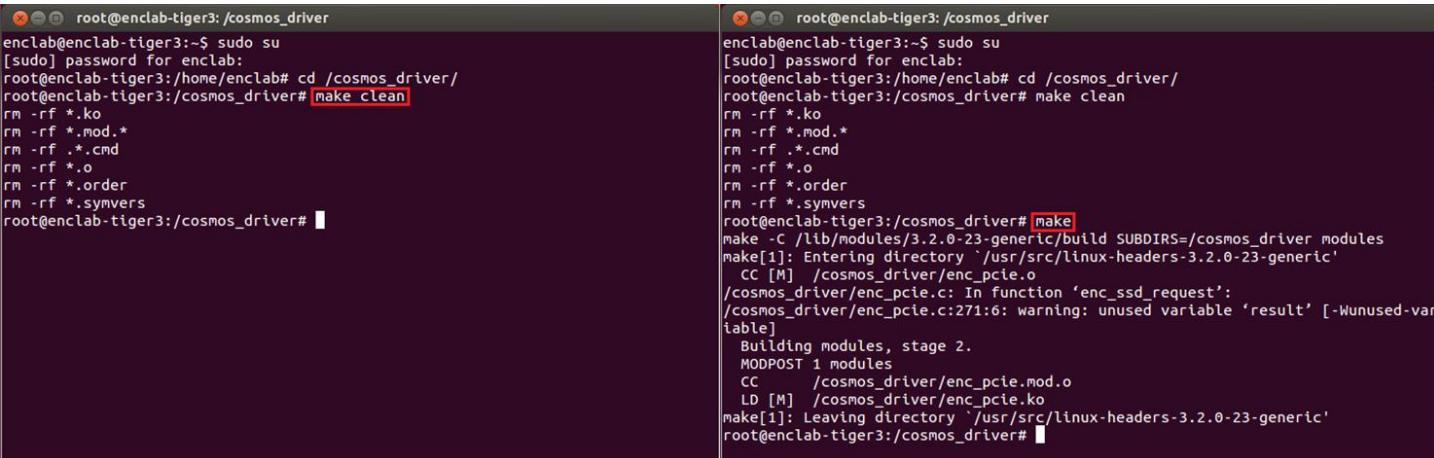


```
root@enclab-tiger3: /cosmos_driver
enclab@enclab-tiger3:~$ sudo su
[sudo] password for enclab:
root@enclab-tiger3:/home/enclab# cd /cosmos_driver/
root@enclab-tiger3:/cosmos_driver#
```

A screenshot of a terminal window titled "root@enclab-tiger3: /cosmos\_driver". The user has run the command "cd /cosmos\_driver/" and is now in the directory, with the prompt "root@enclab-tiger3:/cosmos\_driver#". The command "cd /cosmos\_driver/" is highlighted with a red rectangle.

# Compile Linux Device Driver (2/2)

- Type 'make clean' and 'make'

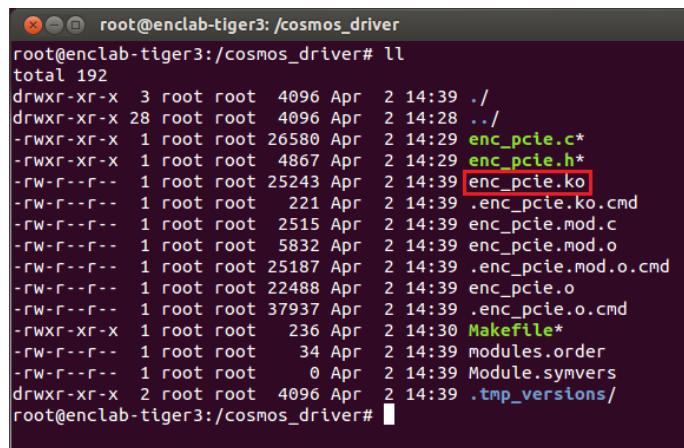


The image shows two side-by-side terminal windows. Both terminals are running as root on the host 'enclab-tiger3' and are located in the directory '/cosmos\_driver'.  
The left terminal shows the command 'make clean' being run, which removes all object files and intermediate files generated by the build process.  
The right terminal shows the command 'make' being run, which performs a full build of the driver modules. It includes steps like CCing the source code, LDing the modules, and finally leaving the directory.

```
root@enclab-tiger3:/cosmos_driver
enclab@enclab-tiger3:~$ sudo su
[sudo] password for enclab:
root@enclab-tiger3:/home/enclab# cd /cosmos_driver/
root@enclab-tiger3:/cosmos_driver# make clean
rm -rf *.ko
rm -rf *.mod.*
rm -rf *.cmd
rm -rf *.o
rm -rf *.order
rm -rf *.symvers
root@enclab-tiger3:/cosmos_driver# 

root@enclab-tiger3:/cosmos_driver
enclab@enclab-tiger3:~$ sudo su
[sudo] password for enclab:
root@enclab-tiger3:/home/enclab# cd /cosmos_driver/
root@enclab-tiger3:/cosmos_driver# make clean
rm -rf *.ko
rm -rf *.mod.*
rm -rf *.cmd
rm -rf *.o
rm -rf *.order
rm -rf *.symvers
root@enclab-tiger3:/cosmos_driver# make
make -C /lib/modules/3.2.0-23-generic/build SUBDIRS=/cosmos_driver modules
make[1]: Entering directory `/usr/src/linux-headers-3.2.0-23-generic'
  CC [M]  /cosmos_driver/enc_pcie.o
/cosmos_driver/enc_pcie.c: In function 'enc_ssd_request':
/cosmos_driver/enc_pcie.c:271:6: warning: unused variable 'result' [-Wunused-variable]
Building modules, stage 2.
MODPOST 1 modules
  CC      /cosmos_driver/enc_pcie.mod.o
  LD [M]  /cosmos_driver/enc_pcie.ko
make[1]: Leaving directory `/usr/src/linux-headers-3.2.0-23-generic'
root@enclab-tiger3:/cosmos_driver#
```

- When compilation is done, 'enc\_pcie.ko' will appear in the folder

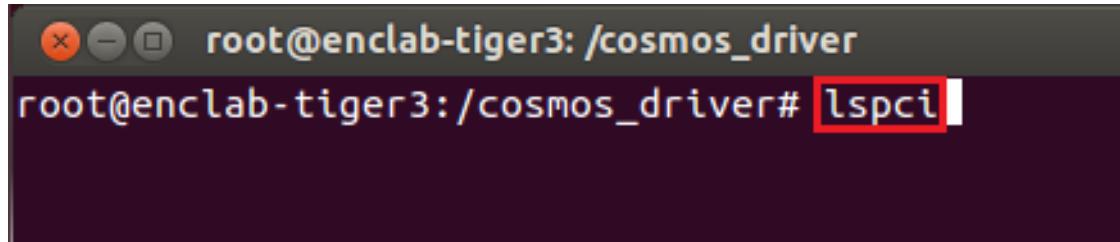


The terminal window shows the command 'll' (ls -l) being run to list the contents of the '/cosmos\_driver' directory. The output shows various files and directories, including the newly compiled kernel module 'enc\_pcie.ko' which is highlighted in red.

```
root@enclab-tiger3:/cosmos_driver
root@enclab-tiger3:/cosmos_driver# ll
total 192
drwxr-xr-x  3 root root  4096 Apr  2 14:39 .
drwxr-xr-x 28 root root  4096 Apr  2 14:28 ..
-rw-r--r--  1 root root 26580 Apr  2 14:29 enc_pcie.c*
-rw-r--r--  1 root root  4867 Apr  2 14:29 enc_pcie.h*
-rw-r--r--  1 root root 25243 Apr  2 14:39 enc_pcie.ko
-rw-r--r--  1 root root   221 Apr  2 14:39 .enc_pcie.ko.cmd
-rw-r--r--  1 root root  2515 Apr  2 14:39 enc_pcie.mod.c
-rw-r--r--  1 root root  5832 Apr  2 14:39 enc_pcie.mod.o
-rw-r--r--  1 root root 25187 Apr  2 14:39 .enc_pcie.mod.o.cmd
-rw-r--r--  1 root root 22488 Apr  2 14:39 enc_pcie.o
-rw-r--r--  1 root root 37937 Apr  2 14:39 .enc_pcie.o.cmd
-rw-r--r--  1 root root   236 Apr  2 14:30 Makefile*
-rw-r--r--  1 root root    34 Apr  2 14:39 modules.order
-rw-r--r--  1 root root     0 Apr  2 14:39 Module.symvers
drwxr-xr-x  2 root root  4096 Apr  2 14:39 .tmp_versions/
root@enclab-tiger3:/cosmos_driver#
```

# Check Device Identification

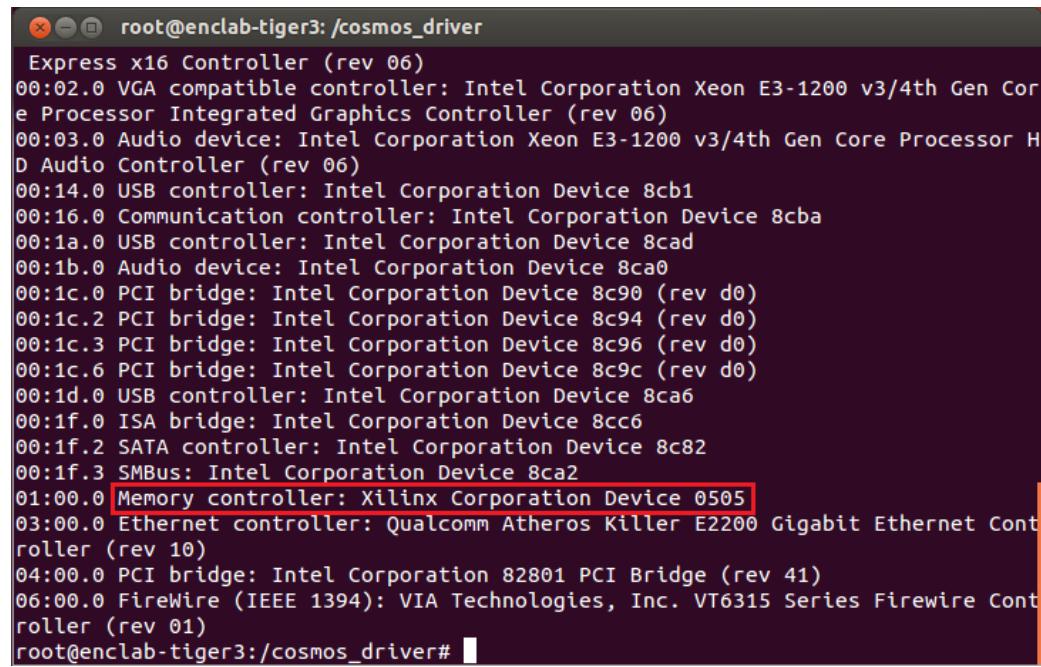
- Before inserting the driver, type 'lspci'



```
root@enclab-tiger3:/cosmos_driver
root@enclab-tiger3:/cosmos_driver# lspci
```

A screenshot of a terminal window titled 'root@enclab-tiger3: /cosmos\_driver'. The user has just typed the command 'lspci' and is awaiting the output.

- Check the Cosmos OpenSSD device in list

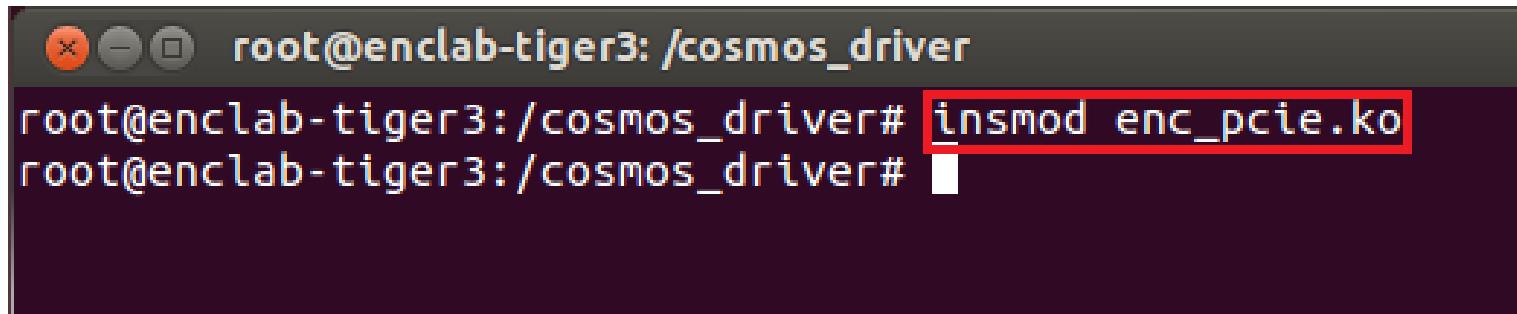


```
root@enclab-tiger3:/cosmos_driver
Express x16 Controller (rev 06)
00:02.0 VGA compatible controller: Intel Corporation Xeon E3-1200 v3/4th Gen Core Processor Integrated Graphics Controller (rev 06)
00:03.0 Audio device: Intel Corporation Xeon E3-1200 v3/4th Gen Core Processor HD Audio Controller (rev 06)
00:14.0 USB controller: Intel Corporation Device 8cb1
00:16.0 Communication controller: Intel Corporation Device 8cba
00:1a.0 USB controller: Intel Corporation Device 8cad
00:1b.0 Audio device: Intel Corporation Device 8ca0
00:1c.0 PCI bridge: Intel Corporation Device 8c90 (rev d0)
00:1c.2 PCI bridge: Intel Corporation Device 8c94 (rev d0)
00:1c.3 PCI bridge: Intel Corporation Device 8c96 (rev d0)
00:1c.6 PCI bridge: Intel Corporation Device 8c9c (rev d0)
00:1d.0 USB controller: Intel Corporation Device 8ca6
00:1f.0 ISA bridge: Intel Corporation Device 8cc6
00:1f.2 SATA controller: Intel Corporation Device 8c82
00:1f.3 SMBus: Intel Corporation Device 8ca2
01:00.0 Memory controller: Xilinx Corporation Device 0505
03:00.0 Ethernet controller: Qualcomm Atheros Killer E2200 Gigabit Ethernet Controller (rev 10)
04:00.0 PCI bridge: Intel Corporation 82801 PCI Bridge (rev 41)
06:00.0 FireWire (IEEE 1394): VIA Technologies, Inc. VT6315 Series Firewire Controller (rev 01)
root@enclab-tiger3:/cosmos_driver#
```

The terminal window shows the output of the 'lspci' command. A red box highlights the 'Memory controller' entry for Xilinx Corporation Device 0505.

# Insert the Driver Module

- Type 'insmod enc\_pcie.ko'

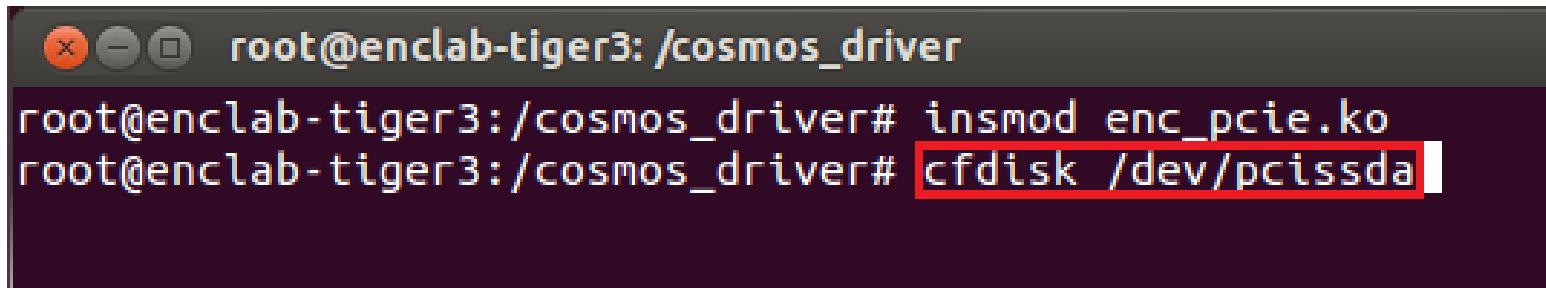


A screenshot of a terminal window titled 'root@enclab-tiger3: /cosmos\_driver'. The window shows a command-line interface where the user has typed 'insmod enc\_pcie.ko'. The command is highlighted with a red rectangle. The terminal window has a dark background and light-colored text.

```
root@enclab-tiger3: /cosmos_driver
root@enclab-tiger3:/cosmos_driver# insmod enc_pcie.ko
root@enclab-tiger3:/cosmos_driver#
```

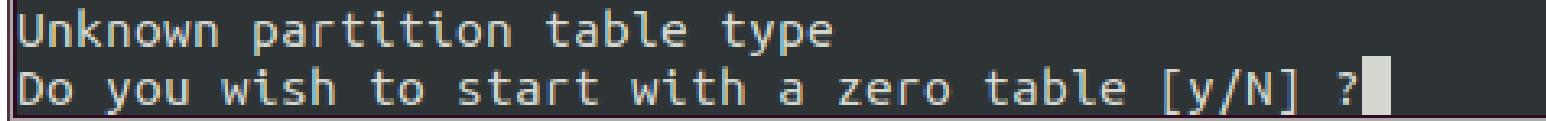
# Disk Partitioning (1/5)

- Type 'cfdisk /dev/pcissda'



```
root@enclab-tiger3:/cosmos_driver# insmod enc_pcie.ko
root@enclab-tiger3:/cosmos_driver# cfdisk /dev/pcissda
```

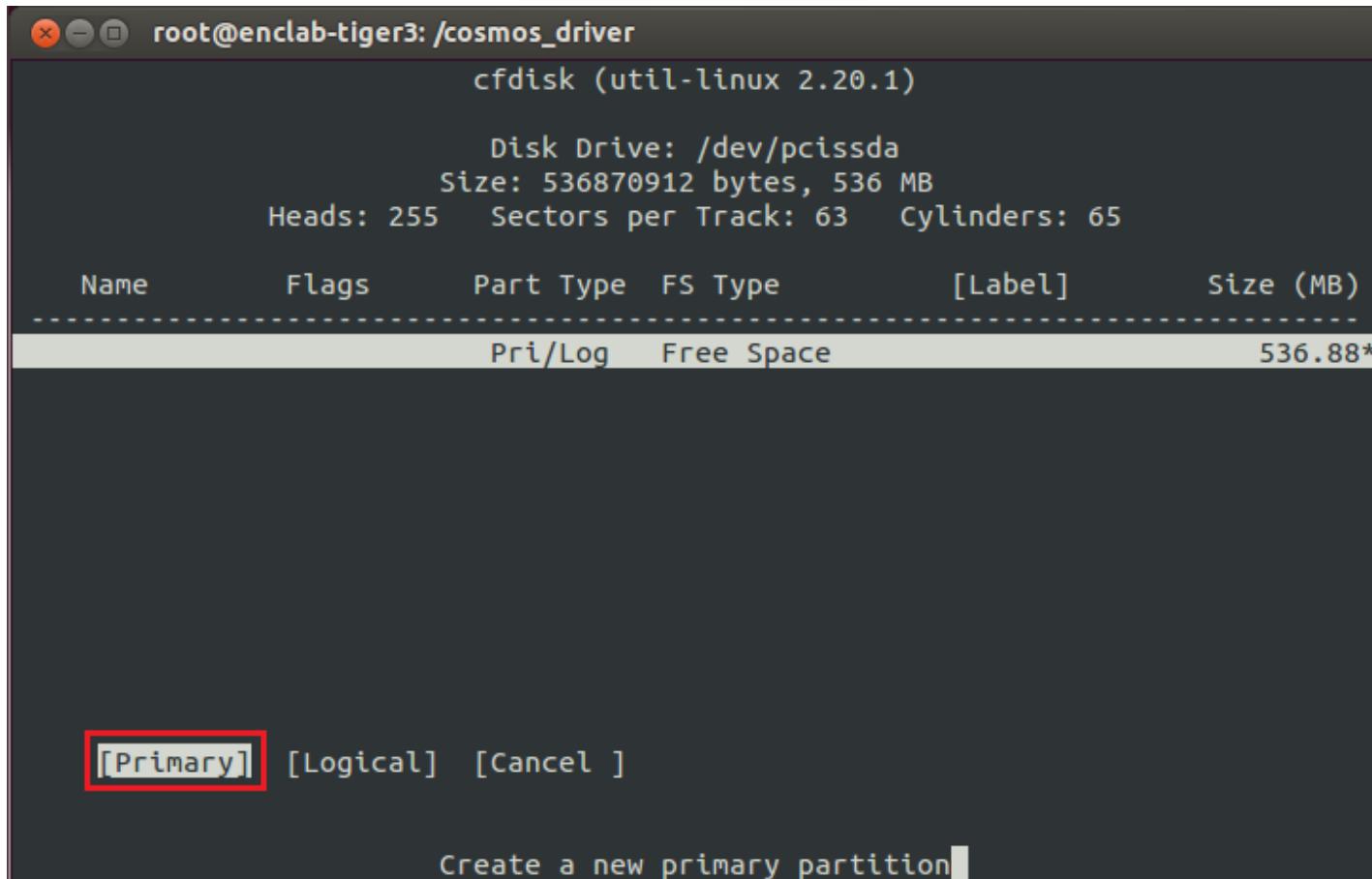
- Type 'y' if following text appears



```
Unknown partition table type
Do you wish to start with a zero table [y/N] ?
```

# Disk Partitioning (2/5)

- Move to 'Primary' and press enter



# Disk Partitioning (3/5)

- Type the size of partition you want and press enter

```
Size (in MB): 536.87
```

- Move to 'Write' and press enter

```
root@enclab-tiger3: /cosmos_driver
cfdisk (util-linux 2.20.1)

Disk Drive: /dev/pcissda
Size: 536870912 bytes, 536 MB
Heads: 255  Sectors per Track: 63  Cylinders: 65

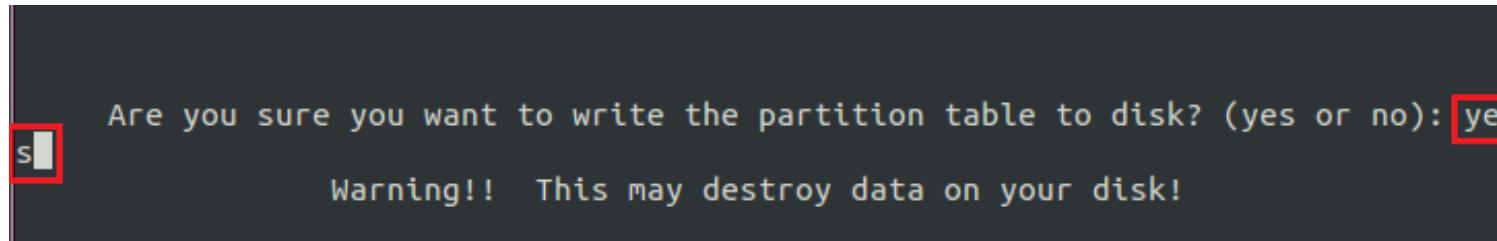
Name      Flags    Part Type  FS Type      [Label]      Size (MB)
-----
pcissda1          Primary  Linux           536.88*
```

[ Bootable ] [ Delete ] [ Help ] [ Maximize ] [ Print ]  
[ Quit ] [ Type ] [ Units ] [ **Write** ]

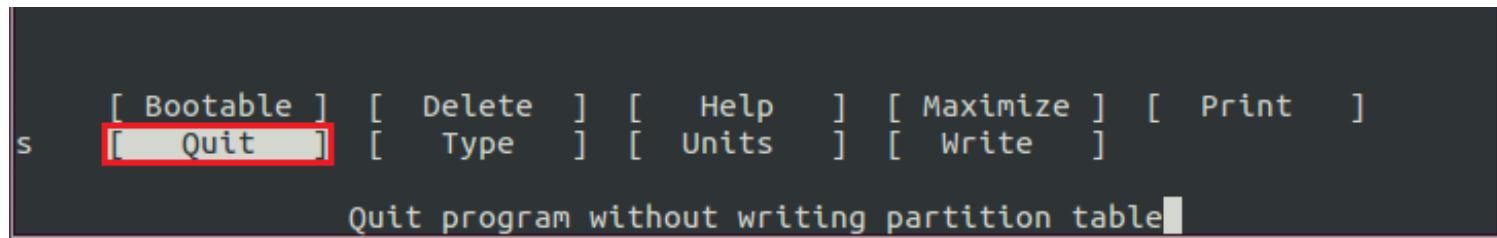
Write partition table to disk (this might destroy data) █

# Disk Partitioning (4/5)

- Type 'yes' and press enter



- Move to 'Quit' and press enter



# Disk Partitioning (5/5)

- Check message

```
root@enclab-tiger3: /cosmos_driver
root@enclab-tiger3: /cosmos_driver# insmod enc_pcie.ko
root@enclab-tiger3: /cosmos_driver# cfdisk /dev/pcissda
Disk has been changed.

WARNING: If you have created or modified any
DOS 6.x partitions, please see the cfdisk manual
page for additional information.
root@enclab-tiger3: /cosmos_driver#
```

# Disk Formatting (1/2)

- Type 'mkfs.ext4 /dev/pcissda1'
  - Formatting time will vary from 5 min to 8 min

```
root@enclab-tiger3: /cosmos_driver
root@enclab-tiger3: /cosmos_driver# insmod enc_pcie.ko
root@enclab-tiger3: /cosmos_driver# cfdisk /dev/pcissda
Disk has been changed.

WARNING: If you have created or modified any
DOS 6.x partitions, please see the cfdisk manual
page for additional information.
root@enclab-tiger3: /cosmos_driver# mkfs.ext4 /dev/pcissda1
```

# Disk Formatting (2/2)

## Check message

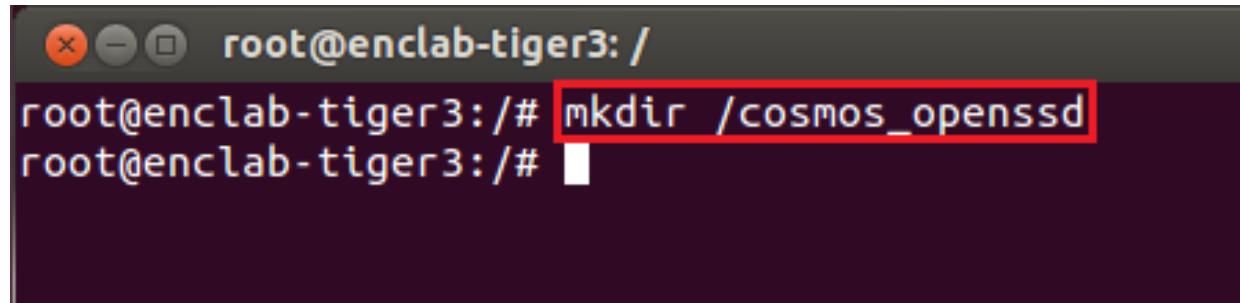
```
root@enclab-tiger3: /cosmos_driver
page for additional information.
root@enclab-tiger3:/cosmos_driver# mkfs.ext4 /dev/pcissda1
mke2fs 1.42 (29-Nov-2011)
Filesystem label=
OS type: Linux
Block size=1024 (log=0)
Fragment size=1024 (log=0)
Stride=0 blocks, Stripe width=0 blocks
131072 inodes, 524256 blocks
26212 blocks (5.00%) reserved for the super user
First data block=1
Maximum filesystem blocks=67633152
64 block groups
8192 blocks per group, 8192 fragments per group
2048 inodes per group
Superblock backups stored on blocks:
    8193, 24577, 40961, 57345, 73729, 204801, 221185, 401409

Allocating group tables: done
Writing inode tables: done
Creating journal (8192 blocks): done
Writing superblocks and filesystem accounting information: done

root@enclab-tiger3:/cosmos_driver#
```

# Disk Mounting (1/2)

- Type 'mkdir' to make a new folder
  - e.g. mkdir /cosmos\_openssd



```
root@enclab-tiger3: /  
root@enclab-tiger3:/# mkdir /cosmos_openssd  
root@enclab-tiger3:/#
```

# Disk Mounting (2/2)

- Type 'mount /dev/pcissda1 <target>' to mount the disk
  - e.g. mount /dev/pcissda1 /cosmosOpenssd
- Type 'df -h' to check the disk if it is mounted properly

```
root@enclab-tiger3:/ # mkdir /cosmosOpenssd
root@enclab-tiger3:/ # mount /dev/pcissda1 /cosmosOpenssd
root@enclab-tiger3:/ # df -h
Filesystem      Size  Used Avail Use% Mounted on
/dev/sda2       218G   15G  193G  7% /
udev            1.9G  4.0K  1.9G  1% /dev
tmpfs           382M  784K  381M  1% /run
none             5.0M    0  5.0M  0% /run/lock
none             1.9G  128K  1.9G  1% /run/shm
/dev/pcissda1   509M   24M  460M  5% /cosmosOpenssd
root@enclab-tiger3:/ #
```

# Disk Unmounting

- Type 'umount <target>' to unmount the disk
  - e.g. umount /cosmosOpenssd

```
root@enclab-tiger3: /  
root@enclab-tiger3:/# df -h  
Filesystem      Size  Used Avail Use% Mounted on  
/dev/sda2        218G   15G  193G  7% /  
udev            1.9G   4.0K  1.9G  1% /dev  
tmpfs           382M  784K  381M  1% /run  
none            5.0M    0  5.0M  0% /run/lock  
none            1.9G  128K  1.9G  1% /run/shm  
/dev/pcissda1   509M   24M  460M  5% /cosmosOpenssd  
root@enclab-tiger3:/# umount /cosmosOpenssd  
root@enclab-tiger3:/# df -h  
Filesystem      Size  Used Avail Use% Mounted on  
/dev/sda2        218G   15G  193G  7% /  
udev            1.9G   4.0K  1.9G  1% /dev  
tmpfs           382M  784K  381M  1% /run  
none            5.0M    0  5.0M  0% /run/lock  
none            1.9G  128K  1.9G  1% /run/shm  
root@enclab-tiger3:/#
```

# Remove the Driver Module

- Type 'rmmmod <target>/enc\_pcie.ko' to remove the driver module
  - ex. rmmmod /cosmos\_driver/enc\_pcie.ko

```
root@enclab-tiger3: /  
root@enclab-tiger3:/# df -h  
Filesystem      Size  Used Avail Use% Mounted on  
/dev/sda2        218G   15G  193G  7% /  
udev            1.9G  4.0K  1.9G  1% /dev  
tmpfs           382M  784K  381M  1% /run  
none             5.0M    0  5.0M  0% /run/lock  
none             1.9G  128K  1.9G  1% /run/shm  
/dev/pcissda1    509M   24M  460M  5% /cosmos_openssd  
root@enclab-tiger3:/# umount /cosmos_openssd  
root@enclab-tiger3:/# df -h  
Filesystem      Size  Used Avail Use% Mounted on  
/dev/sda2        218G   15G  193G  7% /  
udev            1.9G  4.0K  1.9G  1% /dev  
tmpfs           382M  784K  381M  1% /run  
none             5.0M    0  5.0M  0% /run/lock  
none             1.9G  128K  1.9G  1% /run/shm  
root@enclab-tiger3:/# rmmmod /cosmos_driver/enc_pcie.ko  
root@enclab-tiger3:/#
```