1. **Install Xenomai**

1.1 Check your hardware

Hardware is a big issue in this installation. Since this is really low-level thing, it does not provide support for many different hardware.

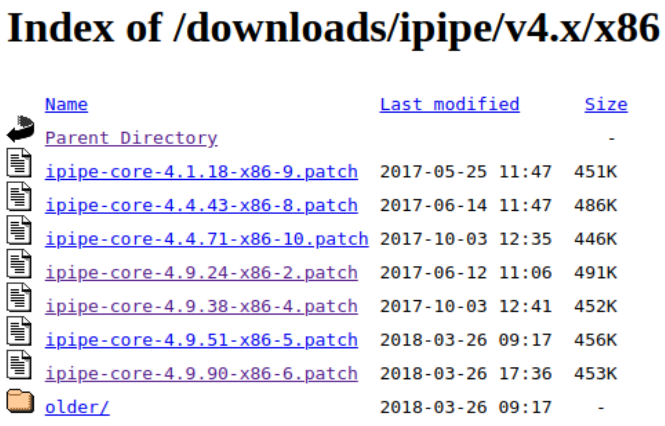
- ☑ **Recommended Hardware**
  - ☑ **Intel/AMD Processor i5/i7** (< 2016 is recommended to guarantee full 16.04 support)
  - ☑ **Dedicated Ethernet controller for RTnet**, with either e1000e/e1000/r8169 driver (Intel PRO/1000 GT recommended)
- ☒ **Warning**
  - ☒ **Nvidia/Ati Drivers** are **NOT** supported (creates a lot of interruptions that breaks the real-time constraints). Please consider removing the dedicated graphic card and use the integrated graphics (Intel HD graphics)

1.2 Choose a Linux Kernel compatible with xenomai

If you have read the part about Xenomai, you should know that ADEOS/I-pipe is underneath the Xenomai Nucleus and Linux Kernel. To make your Xenomai work, you must choose one ADEOS/I-pipe patch, and install one compatible Linux kernel.

> I chose Linux-4.9.90 because it is the latest kernel compatible with ADEOS/I-pipe. You can find the ADEOS/I-pipe patches and their compatibility at https://xenomai.org/downloads/ipipe/

> - The architecture of my CPU is x86_64, the 64-bit edition of x86 architecture. so my patch are find in https://xenomai.org/downloads/ipipe/v4.x/x86/



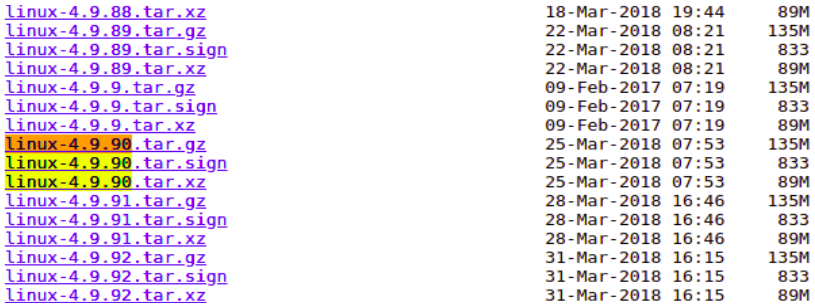
Index of /downloads/ipipe/v4.x/x86

Name	Last modified	Size
Parent Directory		-
ipipe-core-4.1.18-x86-9.patch	2017-05-25 11:47	451K
ipipe-core-4.4.43-x86-8.patch	2017-06-14 11:47	486K
ipipe-core-4.4.71-x86-10.patch	2017-10-03 12:35	446K
ipipe-core-4.9.24-x86-2.patch	2017-06-12 11:06	491K
ipipe-core-4.9.38-x86-4.patch	2017-10-03 12:41	452K
ipipe-core-4.9.51-x86-5.patch	2018-03-26 09:17	456K
ipipe-core-4.9.90-x86-6.patch	2018-03-26 17:36	453K
older/	2018-03-26 09:17	-

As you can see here, the **ipipe-core-4.9.90-x86-6.patch** is the latest. So I chose to install **Linux-4.9.90** for my Xenomai.

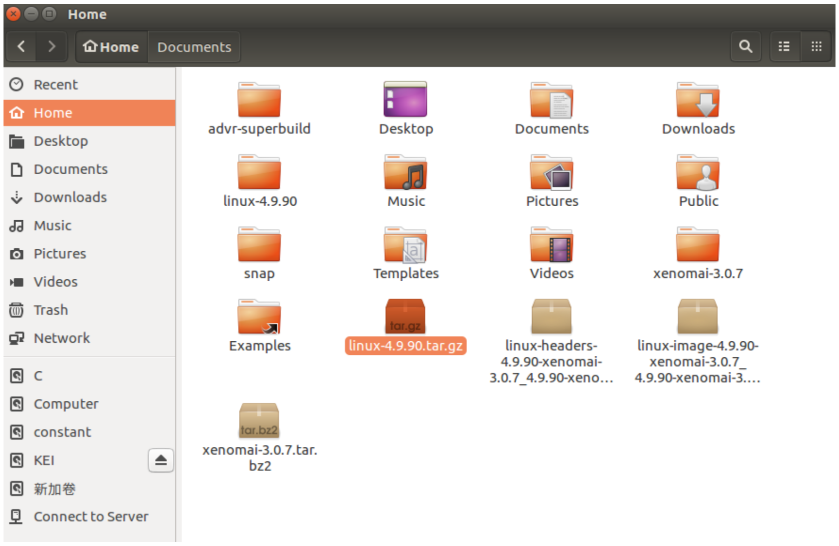
1.3 Go get the linux kernel!

Go to the website: https://mirrors.edge.kernel.org/pub/linux/kernel/v4.x/ , and search for the Linux kernel you are looking for. (tips: If you don't know how to search on website, Ctrl + F normally should work.)



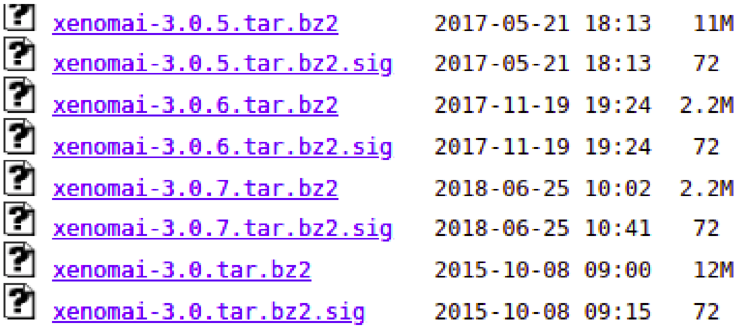
```
linux-4.9.88.tar.xz                                  18-Mar-2018 19:44     89M
linux-4.9.89.tar.gz                                  22-Mar-2018 08:21    135M
linux-4.9.89.tar.sign                                22-Mar-2018 08:21     833
linux-4.9.89.tar.xz                                  22-Mar-2018 08:21     89M
linux-4.9.9.tar.gz                                   09-Feb-2017 07:19    135M
linux-4.9.9.tar.sign                                 09-Feb-2017 07:19     833
linux-4.9.9.tar.xz                                   09-Feb-2017 07:19     89M
linux-4.9.90.tar.gz                                  25-Mar-2018 07:53    135M
linux-4.9.90.tar.sign                                25-Mar-2018 07:53     833
linux-4.9.90.tar.xz                                  25-Mar-2018 07:53     89M
linux-4.9.91.tar.gz                                  28-Mar-2018 16:46    135M
linux-4.9.91.tar.sign                                28-Mar-2018 16:46     833
linux-4.9.91.tar.xz                                  28-Mar-2018 16:46     89M
linux-4.9.92.tar.gz                                  31-Mar-2018 16:15    135M
linux-4.9.92.tar.sign                                31-Mar-2018 16:15     833
linux-4.9.92.tar.xz                                  31-Mar-2018 16:15     89M
```

Now, download linux-4.9.90.tar.gz to your home directory. **Remember put it in the home directory and extract here!**



1.4 Go get Xenomai!

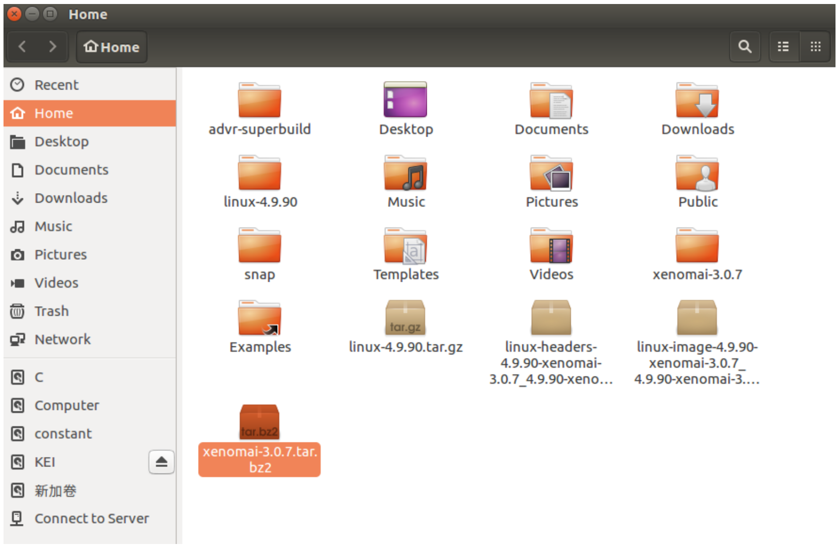
Go to the website: https://xenomai.org/downloads/xenomai/stable/



```
xenomai-3.0.5.tar.bz2          2017-05-21 18:13   11M
xenomai-3.0.5.tar.bz2.sig      2017-05-21 18:13   72
xenomai-3.0.6.tar.bz2          2017-11-19 19:24  2.2M
xenomai-3.0.6.tar.bz2.sig      2017-11-19 19:24   72
xenomai-3.0.7.tar.bz2          2018-06-25 10:02  2.2M
xenomai-3.0.7.tar.bz2.sig      2018-06-25 10:41   72
xenomai-3.0.tar.bz2            2015-10-08 09:00   12M
xenomai-3.0.tar.bz2.sig        2015-10-08 09:15   72
```

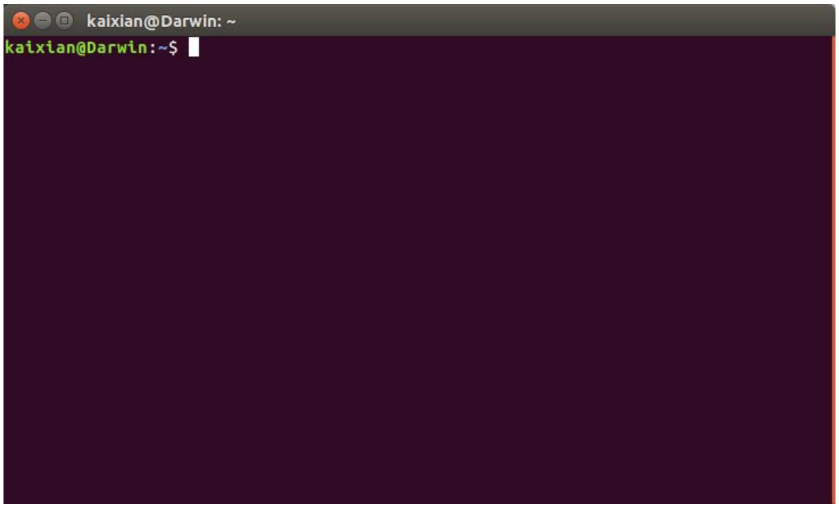
I would suggest you download the newest version. For instance, I downloaded the xenomai-3.0.7.tar.bz2.

Remember to put it in the home directory and extract here!



1.5 Open a terminal (Ctrl+Alt+T)

Now we have Linux and Xenomai, we still need ipipe. To do this, let’s go to the terminal. From now on, we will just use terminal to install Xenomai.



```
kaixian@Darwin:~$ 
```

When you launch your terminal, you will be in your home directory automatically, just as the “~” indicates.

1.6 Apply the Xenomai patch

Now let’s go into linux-4.9.90 directory.

```
cd ~/linux-4.9.90

wget https://xenomai.org/downloads/ipipe/v4.x/x86/ipipe-core-4.9.90-x86-6.patch

../xenomai-3.0.7/scripts/prepare-kernel.sh --arch=x86_64 -ipipe=ipipe-core-4.9.90-x86-6.patch
```

1.7 Config the kernel

Take the actual working config:

```
yes "" | make oldconfig
```

And, then choose one from the following and change your configuration. For some reason, some may not work. In my opinion, anyone working should suffice to configure it successfully)

1) GUI version :

```
make xconfig
# normally, this won’t work because you don’t have qt platform. See the error
message and use the following command to install it. Take qt5 as an example
apt-get install qt5-default
make xconfig
```

2) GTK+ version :

```
sudo apt install gtk+-2.0 glib-2.0 libglade2-dev
make gconfig
```

3) Without GUI :

```
sudo apt install libncurses5-dev
make menuconfig
```

Recommended options for configuration

Actually, these options are correlated, which is to say, some may not be activated unless you change another option. I believe I cannot disable CPU idle PM support until I disabled Processor in the directory of ACPI (Advanced Configuration and Power Interface) Support. So Good Luck on your configuration. Remember not move on to next step before everything below has been done. CHECK TWICE!

1.8 Let’s build the real-time kernel!

Now we have everything we need, let’s build it

```
sudo apt install kernel-package

CONCURRENCY_LEVEL=$(nproc) make-kpkg --rootcmd fakeroot --initrd kernel_image
kernel_headers

cd ..

sudo dpkg -i linux-headers-4.9.90-xenomai-3.0.7_4.9.90-xenomai-3.0.7-
10.00.Custom_amd64.deb linux-image-4.9.90-xenomai-3.0.7_4.9.90-xenomai-3.0.7-
10.00.Custom_amd64.deb
```

1.9 Configure GRUB and reboot

Allow non-root users

```
sudo addgroup xenomai --gid 1234
sudo addgroup root xenomai
sudo usermod -a -G xenomai $USER
```

Edit the grub config :

```
sudo nano /etc/default/grub
```

```
GRUB_DEFAULT="Advanced options for Ubuntu>Ubuntu, with Linux 4.9.90-xenomai-3.0.7"
#GRUB_DEFAULT=saved
#GRUB_SAVEDEFAULT=true
# Comment the following lines
#GRUB_HIDDEN_TIMEOUT=0
#GRUB_HIDDEN_TIMEOUT_QUIET=true
GRUB_TIMEOUT=5
GRUB_CMDLINE_LINUX_DEFAULT="quiet splash xenomai.allowed_group=1234"
GRUB_CMDLINE_LINUX=""
```

❑ If you have an **Intel HD Graphics integrated GPU** (any type) :

```
# This removes powersavings from the graphics, that creates disturbing
interruptions.
GRUB_CMDLINE_LINUX_DEFAULT="quiet splash i915.enable_rc6=0
i915.enable_dc=0 noapic xenomai.allowed_group=1234"
```

Actually, my computer has both Nvidia GPU and Intel GPU, and I believe this is a commom configuration. Xenomai don’t support Nvidia GPU. Therefore, I would highly suggest you do not install Nvidia drive after installing Xenomai. To my defense, after I installed Nvidia drive, I cannot go into GUI anymore.

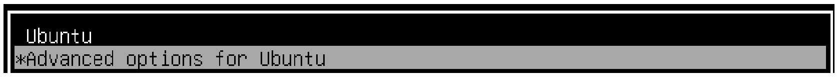
❑ If you have an Intel **Skylake** (2015 processors), you need to add nosmap to fix the latency hang (https://xenomai.org/pipermail/xenomai/2016-October/036787.html) :

```
GRUB_CMDLINE_LINUX_DEFAULT="quiet splash i915.enable_r00636=0
i915.enable_dc=0 xeno_nucleus.xenomai_gid=1234 nosmap"
```

Finally, let’s update GRUB and reboot!

```
sudo update-grub
sudo reboot
```

Now you should have this kernel in your computer, and since you changed your default version via "GRUB_DEFAULT="Advanced options for Ubuntu>Ubuntu, with Linux 4.9.90-xenomai-3.0.7", you should run into this version automatically.



1.10 Make sure your configuration is right

Let's make sure about that, first of all make sure you are running correct kernel:

```
kaixian@Darwin:~$ uname -a
Linux Darwin 4.9.90-xenomai-3.0.7 #1 SMP Fri Aug 10 10:12:50 EDT 2018 x86_64 x86_64
x86_64 GNU/Linux

kaixian@Darwin:~$ dmesg | grep Xenomai
[    0.734215] [Xenomai] scheduling class idle registered.
[    0.734216] [Xenomai] scheduling class rt registered.
[    0.734237] [Xenomai] SMI-enabled chipset found, but SMI workaround disabled
[    0.734271] I-pipe: head domain Xenomai registered.
[    0.734759] [Xenomai] allowing access to group 1234
[    0.734777] [Xenomai] Cobalt v3.0.7 (Lingering Dawn)
```

1.11 Installing User space libraries

```
cd xenomai-3.0.7

./configure --with-pic --with-core=cobalt --enable-smp --disable-tls --enable-
dlopen-libs --disable-clock-monotonic-raw

make -j`nproc`

sudo make install
```

There are also some potential errors in the future, let's avoid that!

```
git clone https://git.xenomai.org/xenomai-3.git

cd xenomai-3

./scripts/bootstrap

./configure --with-pic --with-core=cobalt --enable-smp --disable-tls --enable-
dlopen-libs

make -j`nproc`

sudo make install
```

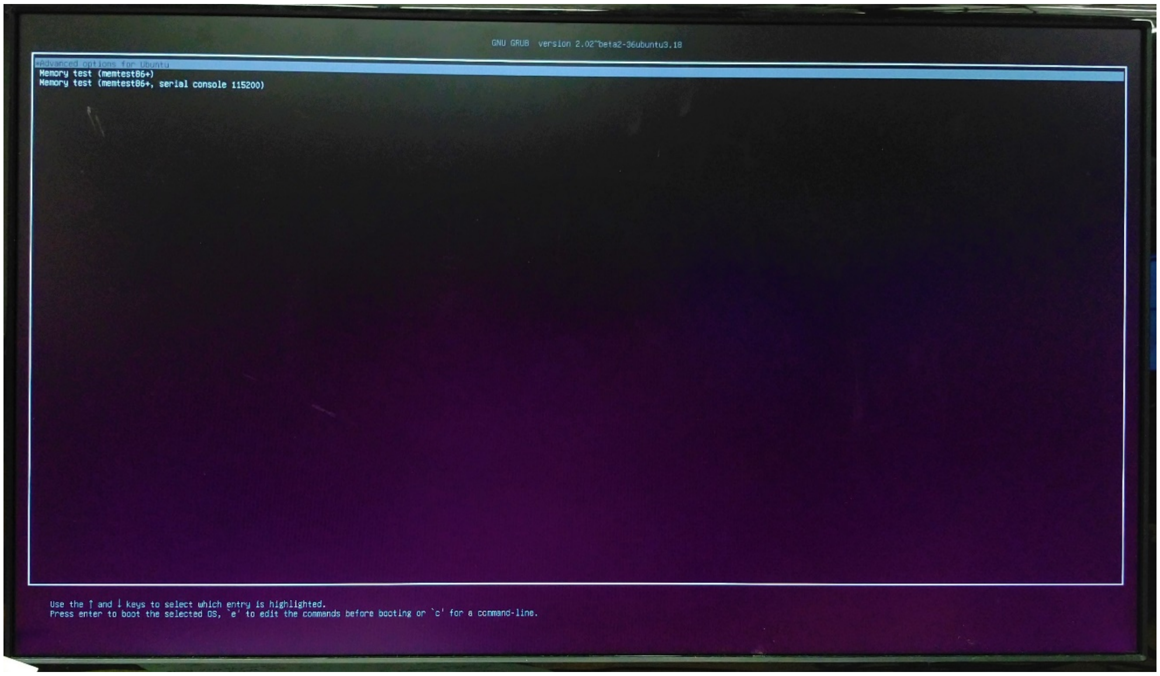
1.12 Your last step: Update your bashrc

```
echo '
### Xenomai
export XENOMAI_ROOT_DIR=/usr/xenomai
export XENOMAI_PATH=/usr/xenomai
export PATH=$PATH:$XENOMAI_PATH/bin:$XENOMAI_PATH/sbin
export PKG_CONFIG_PATH=$PKG_CONFIG_PATH:$XENOMAI_PATH/lib/pkgconfig
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:$XENOMAI_PATH/lib
export OROCOS_TARGET=xenomai
' >> ~/.xenomai_rc

echo 'source ~/.xenomai_rc' >> ~/.bashrc

source ~/.bashrc
```

1.13 Reboot Ubuntu system

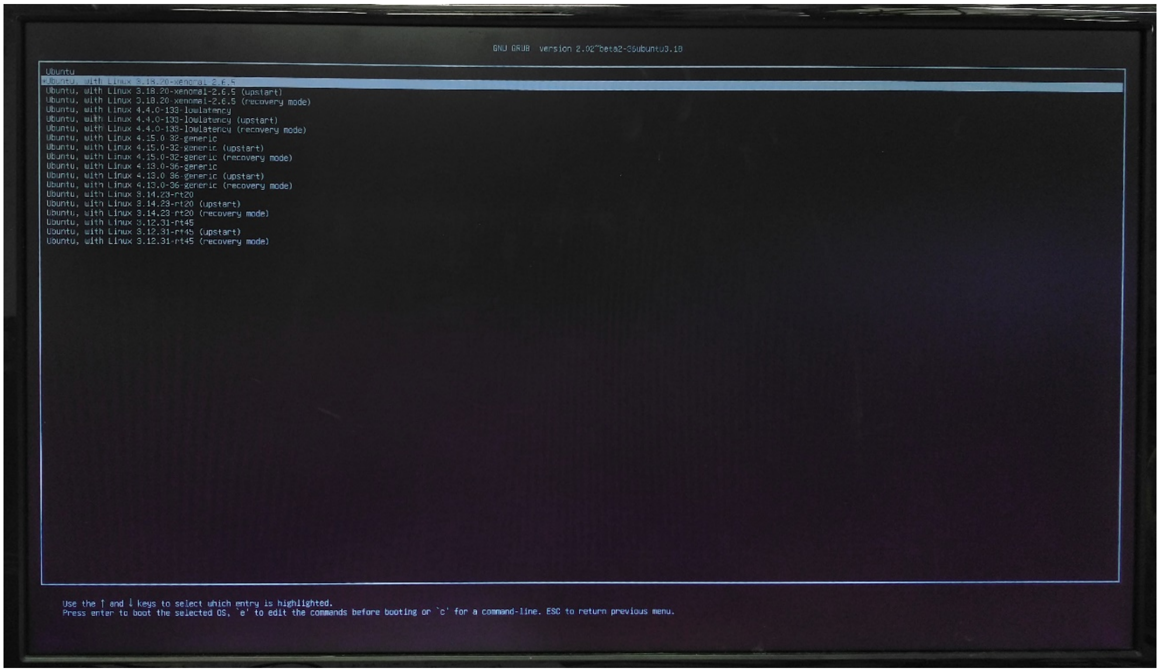
```
sudo reboot
```

After reboot, select “Advanced options for Ubuntu”. See the picture below.



```
                                        GNU GRUB  version 2.02~beta2-36ubuntu3.18

*Advanced options for Ubuntu
 Memory test (memtest86+)
 Memory test (memtest86+, serial console 115200)

   Use the ↑ and ↓ keys to select which entry is highlighted.
   Press enter to boot the selected OS, `e' to edit the commands before booting or `c' for a command-line.
```

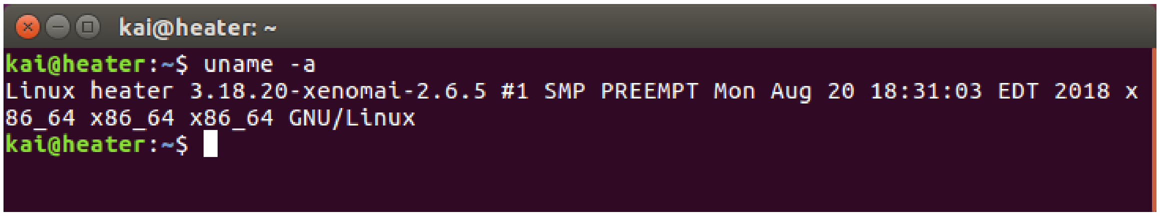
Under this directory, you should be able to see one option end with “–rtXX”. Use ↑ ↓ to select it and press “ENTER” key. Now, wait for it to finish the rebooting.



```
GNU GRUB  version 2.02~beta2-36ubuntu3.18

 Ubuntu
*Ubuntu, with Linux 3.18.20-xenomai-2.6.5
 Ubuntu, with Linux 3.18.20-xenomai-2.6.5 (upstart)
 Ubuntu, with Linux 3.18.20-xenomai-2.6.5 (recovery mode)
 Ubuntu, with Linux 4.4.0-133-lowlatency
 Ubuntu, with Linux 4.4.0-133-lowlatency (upstart)
 Ubuntu, with Linux 4.4.0-133-lowlatency (recovery mode)
 Ubuntu, with Linux 4.15.0-32-generic
 Ubuntu, with Linux 4.15.0-32-generic (upstart)
 Ubuntu, with Linux 4.15.0-32-generic (recovery mode)
 Ubuntu, with Linux 4.13.0-36-generic
 Ubuntu, with Linux 4.13.0-36-generic (upstart)
 Ubuntu, with Linux 4.13.0-36-generic (recovery mode)
 Ubuntu, with Linux 3.14.23-rt20
 Ubuntu, with Linux 3.14.23-rt20 (upstart)
 Ubuntu, with Linux 3.14.23-rt20 (recovery mode)
 Ubuntu, with Linux 3.12.31-rt45
 Ubuntu, with Linux 3.12.31-rt45 (upstart)
 Ubuntu, with Linux 3.12.31-rt45 (recovery mode)

Use the ↑ and ↓ keys to select which entry is highlighted.
Press enter to boot the selected OS, `e' to edit the commands before booting or `c' for a command-line. ESC to return previous menu.
```

After the reboot, let's see your current kernel with the following command.

```
uname -a
```



```
kai@heater:~$ uname -a
Linux heater 3.18.20-xenomai-2.6.5 #1 SMP PREEMPT Mon Aug 20 18:31:03 EDT 2018 x
86_64 x86_64 x86_64 GNU/Linux
kai@heater:~$
```

If it matches the one you chose, then you installation is succeed! Congratulations !

2. Test your latency

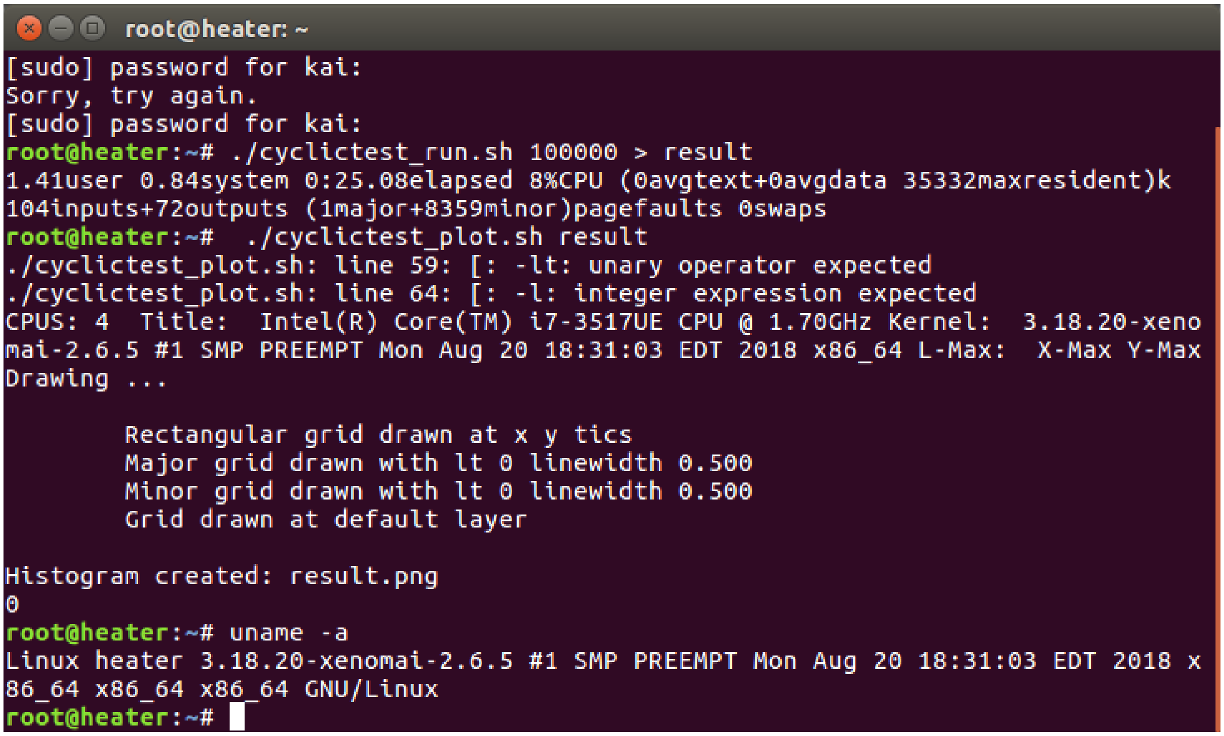
To test your latency, first make sure that you have cyclictest_run.sh and cyclictest_plot.sh and make them executable using chmod +x command.

```
./cyclictest_run.sh 100000 > result
```

Wait for a few minutes. This command creates a file named “result” containing the testing result. Then,

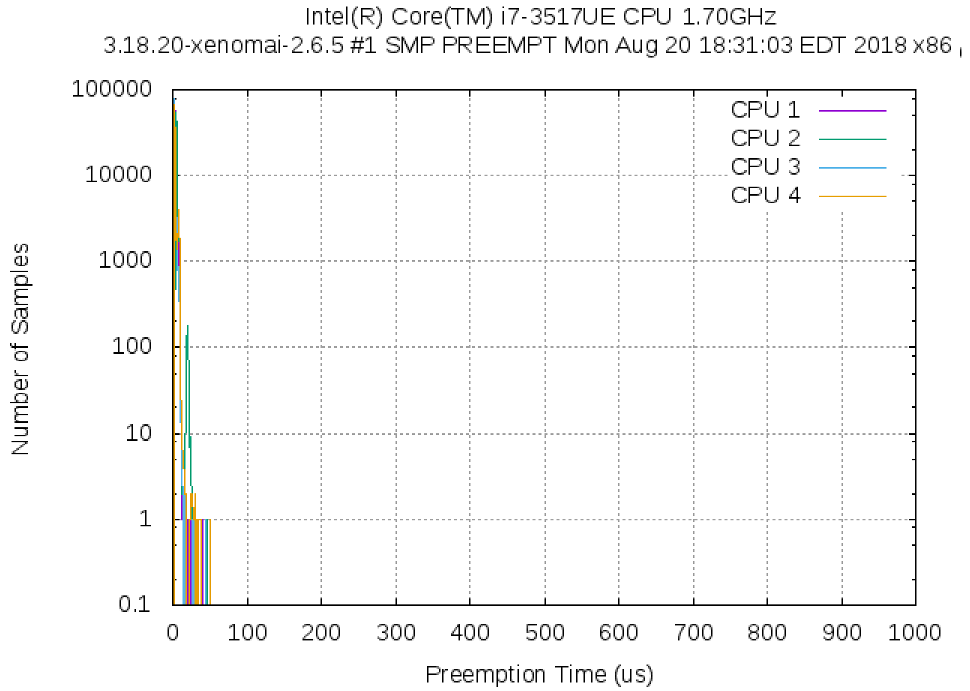
```
./cyclictest_plot.sh result
```

This command visualizes your data and put it in result.png in your current directory.

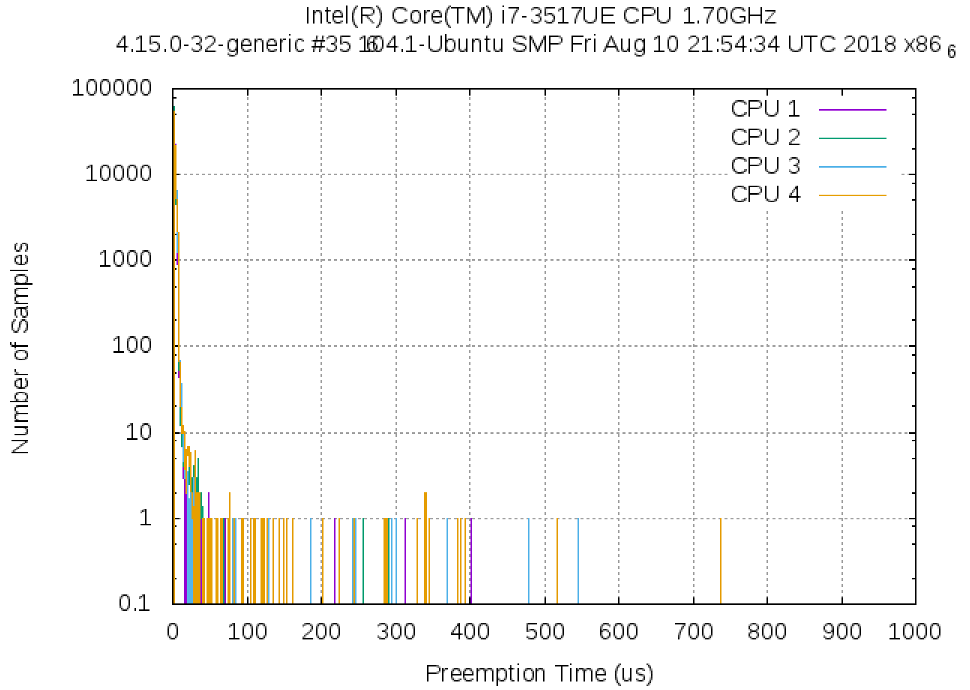


```
[sudo] password for kai:
Sorry, try again.
[sudo] password for kai:
root@heater:~# ./cyclictest_run.sh 100000 > result
1.41user 0.84system 0:25.08elapsed 8%CPU (0avgtext+0avgdata 35332maxresident)k
104inputs+72outputs (1major+8359minor)pagefaults 0swaps
root@heater:~#  ./cyclictest_plot.sh result
./cyclictest_plot.sh: line 59: [: -lt: unary operator expected
./cyclictest_plot.sh: line 64: [: -l: integer expression expected
CPUS: 4  Title:  Intel(R) Core(TM) i7-3517UE CPU @ 1.70GHz Kernel:  3.18.20-xeno
mai-2.6.5 #1 SMP PREEMPT Mon Aug 20 18:31:03 EDT 2018 x86_64 L-Max:  X-Max Y-Max
Drawing ...

        Rectangular grid drawn at x y tics
        Major grid drawn with lt 0 linewidth 0.500
        Minor grid drawn with lt 0 linewidth 0.500
        Grid drawn at default layer

Histogram created: result.png
0
root@heater:~# uname -a
Linux heater 3.18.20-xenomai-2.6.5 #1 SMP PREEMPT Mon Aug 20 18:31:03 EDT 2018 x
86_64 x86_64 x86_64 GNU/Linux
root@heater:~#
```

The following picture shows the latency test result for –rt kernel.



And you can compare it to latency result for –generic kernel



The preemption time here actually stands for latency. As you can see, the latency dropped dramatically!