Application note No. 2: creating an embedded Linux solution and image application

Embedded Linux solution project objectives

This is the second of three application notes for creating imaging solutions using the 96Boards onsemi Dual Camera Mezzanine and Ultra96V2.

This project demonstrates how to build the embedded Linux solution by using the 96Boards onsemi Dual Camera Mezzanine with the Avnet Ultra96V2 board.

The expected outcome of this project is a bootable SD card with the embedded Linux OS. When this SD card is inserted into the Ultra96 with 96Boards onsemi Dual Camera Mezzanine, it will enable the capture video and display it on a Display Port Monitor.

Getting started: requirements

The following hardware is required to follow this series of application notes:

- Ultra96V2
- Ultra96V2 power supply
- 96Boards onsemi Dual Camera Mezzanine
- SD card
- JTAG / USB adaptor
- Display port capable monitor
- Mini-display port cable
- 16 GB SD card

To implement this series of application notes, you need the following Xilinx software installed:

- Vitis 2020.1, includes Vivado 2020.1
- PetaLinux 2020.1
- Git
- Terminal application

You'll need a few licenses for this implementation. Bitstreams for the Xilinx ZU3EG device can be generated license-free as part of the Xilinx Vivado webPACK. However, some of the IP used within this design requires an additional license. This license is provided with the Ultra96V2 and is marked "OEM Zynq ZU3 Ultra96 Vivado Design Edition with SDSoC Voucher Pack." Redeem this license and install it on the machine you're using to implement the project. Once it is installed, you can use the license manager to see the licensed IP, including the On-Screen Display (OSD).

What is PetaLinux?

PetaLinux is a set of build tools that enables us to create an embedded Linux solution for Xilinx processors (A9, A53, A72 & MicroBlaze) using a x86 Linux host (see Figure 1).

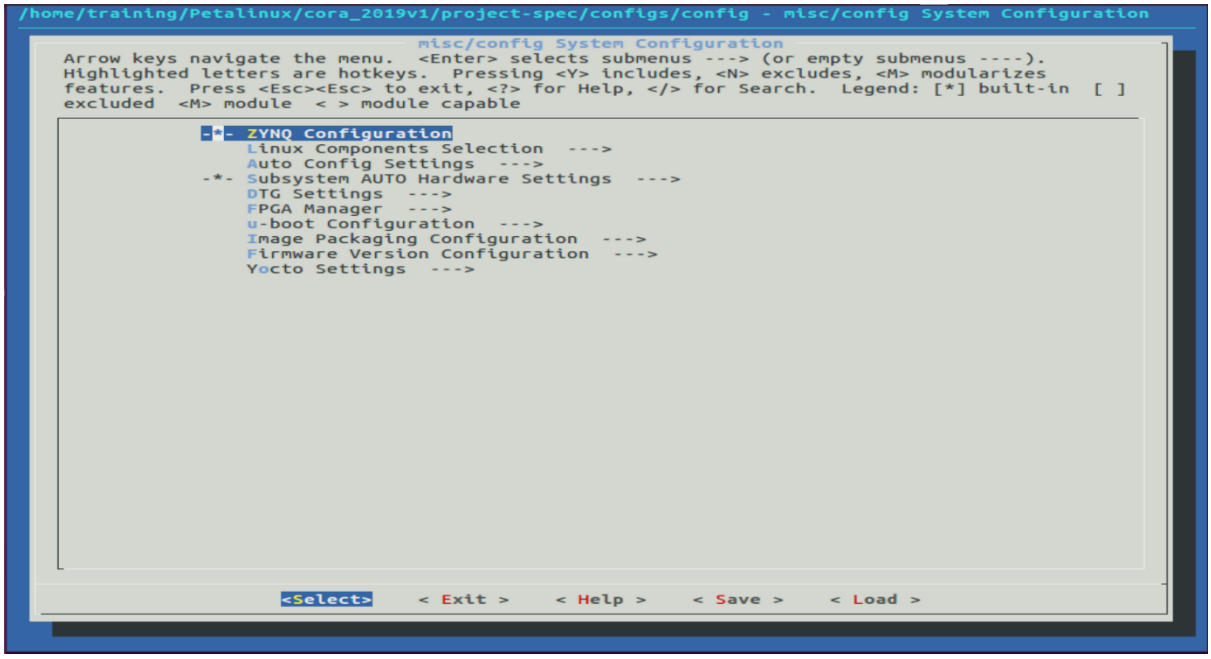


Figure 1. PetaLinux configuration menu

At the highest level, PetaLinux consists of seven commands. These commands are used to create projects, applications, boot and deploy the embedded Linux OS.

The commands are:

- petalinux-create — This command is used to create projects, apps and modules. When creating projects, we need to define either a template, which can be zynq, zynqMP or microblaze. Alternatively, we can define a source with an existing PetaLinux board support package.
- petalinux-config — This allows configuration of a specific element of the OS e.g. the kernel or the root file system. This also enables configuration of the OS for a new hardware definition using the “get-hw-description” option.
- petalinux-build — This command builds the embedded Linux project, a component of the project or the Yocto e-SDK.
- petalinux-boot — This command enables us to boot the project on our target board using JTAG or to boot the project in the simulation environment in QEMU.
- petalinux-package — At the end of the project build, we may want to package the project to create a boot.bin that can be used in conjunction with the Kernel and RootFS to boot the system. This command can also be used to package the project as a Board Support Package.
- petalinux-upgrade — This command provides for the upgrading between different versions of PetaLinux.
- petalinux-util — This command provides several services used in development and debugging.

Building embedded Linux operating system

1. Change the directory in the project that contains the hardware design created in the first application note. This is the directory that contains the cloned Avnet HDL and BDF repositories.

```
File  Edit  View  Search  Terminal  Help
adiuvo@Adiuvo:~$ cd hdl_projects/
adiuvo@Adiuvo:~/hdl_projects$ cd avnet_imaging/
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging$ git clone https://github.com/Avnet/petalinux.git
```

2. Clone the Avnet PetaLinux directory using the command *git clone* *https://github.com/Avnet/petalinux.git*

```
File  Edit  View  Search  Terminal  Help
adiuvo@Adiuvo:~$ cd hdl_projects/
adiuvo@Adiuvo:~/hdl_projects$ cd avnet_imaging/
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging$ git clone https://github.com/Avnet/petalinux.git
Cloning into 'petalinux'...
remote: Enumerating objects: 113, done.
remote: Counting objects: 100% (113/113), done.
remote: Compressing objects: 100% (59/59), done.
remote: Total 2943 (delta 81), reused 73 (delta 49), pack-reused 2830
Receiving objects: 100% (2943/2943), 6.13 MiB | 4.45 MiB/s, done.
Resolving deltas: 100% (1599/1599), done.
```

3. With the repositories cloned, the next step is to ensure we check out the correct branch from the master. For the bdf repository, we want to work from the master branch. To do this, we cd into the newly cloned bf folder and execute the command *git checkout master*

```
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging$ cd bdf
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/bdf$ git checkout master
Already on 'master'
Your branch is up-to-date with 'origin/master'.
```

4. For the HDL branch, we want to check out the 2020.1 branch. Use the command *git check out 2020.1* again from within the HDL folder.

```
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/bdf$ cd ../hdl
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/hdl$ git checkout 2020.1
Already on '2020.1'
Your branch is up-to-date with 'origin/2020.1'.
```

5. For the petalinux branch, we want to check out the 2020.1 branch. Use the command *git checkout 2020.1* again from within the petalinux folder.

```
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/hdl$ cd ../petalinux/
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/petalinux$ git checkout 2020.1
Branch '2020.1' set up to track remote branch '2020.1' from 'origin'.
Switched to a new branch '2020.1'
```

6. The petalinux image will be built using a script. In the petalinux directory, enter the command ./scripts/make_ultra96v2_dualcam.sh

```
File  Edit  View  Search  Terminal  Help
adiuvo@Adiuvo:~$ cd hdl_projects/
adiuvo@Adiuvo:~/hdl_projects$ cd avnet_imaging/
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging$ git clone https://github.com/Avnet/petalinux.git
Cloning into 'petalinux'...
remote: Enumerating objects: 113, done.
remote: Counting objects: 100% (113/113), done.
remote: Compressing objects: 100% (59/59), done.
remote: Total 2943 (delta 81), reused 73 (delta 49), pack-reused 2830
Receiving objects: 100% (2943/2943), 6.13 MiB | 4.45 MiB/s, done.
Resolving deltas: 100% (1599/1599), done.
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging$ cd bdf
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/bdf$ git checkout master
Already on 'master'
Your branch is up-to-date with 'origin/master'.
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/bdf$ cd ../hdl
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/hdl$ git checkout 2020.1
Already on '2020.1'
Your branch is up-to-date with 'origin/2020.1'.
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/hdl$ cd ../petalinux/
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/petalinux$ git checkout 2020.1
Branch '2020.1' set up to track remote branch '2020.1' from 'origin'.
Switched to a new branch '2020.1'
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/petalinux$ ./scripts/make_ultra96v2_dualcam.sh
```

7. Depending on the capabilities of the development machine, the creation of the petalinux image may take some time.

```
File  Edit  View  Search  Terminal  Help
0x00000000    0x0054F89B    Feb 11 13:46:12 2021    ./images/linux/system.bit
0 Infos, 0 Warnings, 0 Critical Warnings and 0 Errors encountered.
write_cfgmem completed successfully
INFO: [Common 17-206] Exiting Vivado at Thu Feb 11 16:11:02 2021...
INFO: Cleaning pre-built folder
INFO: Updating software prebuilt
INFO: Installing software images
INFO: Pre-built directory is updated.
/home/adiuvo/hdl_projects/avnet_imaging/petalinux/projects/ultra96v2_dualcam_2020_1
INFO: Target BSP "/home/adiuvo/hdl_projects/avnet_imaging/petalinux/projects/ultra96v2_dualcam_2020_1.bsp" will contain the follo
ing projects
INFO: PetaLinux project: /home/adiuvo/hdl_projects/avnet_imaging/petalinux/projects/ultra96v2_dualcam_2020_1
INFO: sourcing build environment
INFO:   Copying /home/adiuvo/hdl_projects/avnet_imaging/petalinux/projects/ultra96v2_dualcam_2020_1/config.project
INFO:   Copying /home/adiuvo/hdl_projects/avnet_imaging/petalinux/projects/ultra96v2_dualcam_2020_1/.petalinux
INFO:   Copying /home/adiuvo/hdl_projects/avnet_imaging/petalinux/projects/ultra96v2_dualcam_2020_1/.gitignore
INFO:   Copying /home/adiuvo/hdl_projects/avnet_imaging/petalinux/projects/ultra96v2_dualcam_2020_1/pre-built
INFO:   Copying /home/adiuvo/hdl_projects/avnet_imaging/petalinux/projects/ultra96v2_dualcam_2020_1/project-spec
INFO:   Copying /home/adiuvo/hdl_projects/avnet_imaging/petalinux/projects/ultra96v2_dualcam_2020_1/components
INFO:   Copying hardware project /home/adiuvo/hdl_projects/avnet_imaging/hdl/Projects/ultra96v2_dualcam/ULTRA96V2_2020_1
INFO: Creating BSP
INFO: Generating package ultra96v2_dualcam_2020_1.bsp...
INFO: BSP is ready
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/petalinux$
```

8. Once the script completes, we now have all the necessary elements to load onto a SD card. The next stage is to format the SD card so that it is correctly formatted to hold the embedded Linux OS.

Creating the SD card

1. Insert the SD card into your development machine. Run the command ls /dev/sd* and this will list the SD card. Note that your SD card may show a different ID number than what is demonstrated here, so please be careful as incorrect identification could damage your wider system.

```
File  Edit  View  Search  Terminal  Help
adiuvo@Adiuvo:~$ ls /dev/sd*
/dev/sda  /dev/sda1  /dev/sda2
adiuvo@Adiuvo:~$
```

2. Unmount the partitions using the umount command *umount /dev/sda1 umount /dev/sda2* .

```
File  Edit  View  Search  Terminal  Help
adiuvo@Adiuvo:~$ ls /dev/sd*
/dev/sda  /dev/sda1  /dev/sda2
adiuvo@Adiuvo:~$ umount /dev/sda1
adiuvo@Adiuvo:~$ umount /dev/sda2
adiuvo@Adiuvo:~$
```

3. Run the command *sudo fdisk /dev/sda* and this will start fdisk. Press p to view the current partitions (if any on the SD card).

```
File  Edit  View  Search  Terminal  Help
/dev/sda  /dev/sda1  /dev/sda2
adiuvo@Adiuvo:~$ umount /dev/sda1
adiuvo@Adiuvo:~$ umount /dev/sda2
adiuvo@Adiuvo:~$ sudo fdisk /dev/sda
[sudo] password for adiuvo:

Welcome to fdisk (util-linux 2.31.1).
Changes will remain in memory only, until you decide to write them.
Be careful before using the write command.


Command (m for help): p
Disk /dev/sda: 14.9 GiB, 16022241280 bytes, 31293440 sectors
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
Disklabel type: dos
Disk identifier: 0xe5955884

Device     Boot  Start      End  Sectors  Size Id Type
/dev/sda1  *      2048   206847   204800  100M  c W95 FAT32 (LBA)
/dev/sda2       206848 31293439 31086592 14.8G 83 Linux

Command (m for help):
```

4. The next step is to delete any existing partitions. Enter d then 1 to delete partition one, and then enter d again and the remaining partition will be removed.

```
File  Edit  View  Search  Terminal  Help


Command (m for help): p
Disk /dev/sda: 14.9 GiB, 16022241280 bytes, 31293440 sectors
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
Disklabel type: dos
Disk identifier: 0xe5955884

Device     Boot  Start      End  Sectors  Size Id Type
/dev/sda1  *      2048   206847   204800  100M  c W95 FAT32 (LBA)
/dev/sda2       206848 31293439 31086592 14.8G 83 Linux

Command (m for help): d
Partition number (1,2, default 2): 1

Partition 1 has been deleted.

Command (m for help): d
Selected partition 2
Partition 2 has been deleted.

Command (m for help):
```

5. To create a new partition, enter p then 1, followed by 2048 and final +1G to create a 1GB partition. This will become the boot partition.

```
Command (m for help): n
Partition type
   p   primary (0 primary, 0 extended, 4 free)
   e   extended (container for logical partitions)
Select (default p): p
Partition number (1-4, default 1): 1
First sector (2048-31293439, default 2048): 2048
Last sector, +sectors or +size{K,M,G,T,P} (2048-31293439, default 31293439): +1G
```

6. To make this partition bootable, enter the command a.

```
Command (m for help): a
Selected partition 1
The bootable flag on partition 1 is enabled now.

Command (m for help):
```

7. To create the second partition, enter the command n, followed by 2, then press enter twice to use the remaining space on the SD card.

```
Command (m for help): n
Partition type
   p   primary (1 primary, 0 extended, 3 free)
   e   extended (container for logical partitions)
Select (default p): p
Partition number (2-4, default 2): 2
First sector (2099200-31293439, default 2099200):
Last sector, +sectors or +size{K,M,G,T,P} (2099200-31293439, default 31293439):

Created a new partition 2 of type 'Linux' and of size 13.9 GiB.

Command (m for help):
```

8. Pressing p again shows the newly created partitions.

```
Command (m for help): p
Disk /dev/sda: 14.9 GiB, 16022241280 bytes, 31293440 sectors
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
Disklabel type: dos
Disk identifier: 0xe5955884

Device     Boot   Start      End  Sectors  Size Id Type
/dev/sda1  *       2048  2099199  2097152    1G 83 Linux
/dev/sda2       2099200 31293439 29194240 13.9G 83 Linux

Filesystem/RAID signature on partition 1 will be wiped.

Command (m for help):
```

9. Finally, enter the w command to write the partitions to the SD card.

```
Command (m for help): w
The partition table has been altered.
Calling ioctl() to re-read partition table.
Synching disks.
```

10. With the partitions created, the next step is to format the two partitions correctly. To configure the first partition, enter the command *sudo mkfs.vfat -F 32 -n boot /dev/sda1*. This formats the partition as FAT32 with the name of boot.

```
adiuvo@Adiuvo:~$ sudo mkfs.vfat -F 32 -n boot /dev/sda1
mkfs.fat 4.1 (2017-01-24)
mkfs.fat: warning - lowercase labels might not work properly with DOS or Windows
adiuvo@Adiuvo:~$
```

11. For the second partition, enter the command *sudo mkfs.ext4 -L root /dev/sda2*. This will format the second partition as EXT4 and name it root.

```
adiuvo@Adiuvo:~$ sudo mkfs.ext4 -L root /dev/sda2
mke2fs 1.44.1 (24-Mar-2018)
Creating filesystem with 3649280 4k blocks and 913920 inodes
Filesystem UUID: 3e0696e2-5245-440f-93a5-7dd20a0e205a
Superblock backups stored on blocks:
        32768, 98304, 163840, 229376, 294912, 819200, 884736, 1605632, 2654208

Allocating group tables: done
Writing inode tables: done
Creating journal (16384 blocks): done
Writing superblocks and filesystem accounting information: done
```

12. Now we are ready to write the generated files to the SD card change directory into the petalinux/projects/ultra96v2_dualcam_2020_1 directory. Enter the following commands to write the boot.bin, SCR and Linux image to the boot partition.

    cp ./images/linux/BOOT.BIN /media/<user name>/UID of FAT32 partition>/.

    cp ./images/linux/boot.scr /media/<user name>/<UUID of FAT32 partition>/.

    cp ./images/linux/image.ub /media/<user name>/<UUID of FAT32 partition>/.

```
adiuvo@Adiuvo:~$ cd hdl_projects/avnet_imaging/petalinux/projects/ultra96v2_dualcam_2020_1/
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/petalinux/projects/ultra96v2_dualcam_2020_1$ cp ./images/linux/BOOT.BIN /media/adiuvo/boo
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/petalinux/projects/ultra96v2_dualcam_2020_1$ cp ./images/linux/boot.scr /media/adiuvo/boo
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/petalinux/projects/ultra96v2_dualcam_2020_1$ cp ./images/linux/image.ub /media/adiuvo/boo
```

13. To write the root file system to the root partition, we need to enter the command *sudo tar xvf ./images/linux/rootfs.tar.gz -C /media//<user name>/<UUID of ext4 partition>/* .

```
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/petalinux/projects/ultra96v2_dualcam_2020_1$ sudo tar xvf ./images/linux/rootfs.tar.gz -C /media/adiuvo/root/
./
./etc/
./etc/tmpfiles.d/
./etc/tmpfiles.d/dnf.conf
./etc/avahi/
./etc/avahi/hosts
./etc/avahi/services/
./etc/avahi/services/sftp-ssh.service
./etc/avahi/services/ssh.service
./etc/avahi/avahi-daemon.conf
./etc/mke2fs.conf
./etc/ssh/
./etc/ssh/sshd_config_readonly
./etc/ssh/sshd_config
./etc/ssh/ssh_config
./etc/ssh/moduli
./etc/rpcbind.conf
./etc/sudoers.dist
./etc/modprobe.d/
./etc/fonts/
./etc/fonts/conf.d/
./etc/fonts/conf.d/40-nonlatin.conf
```

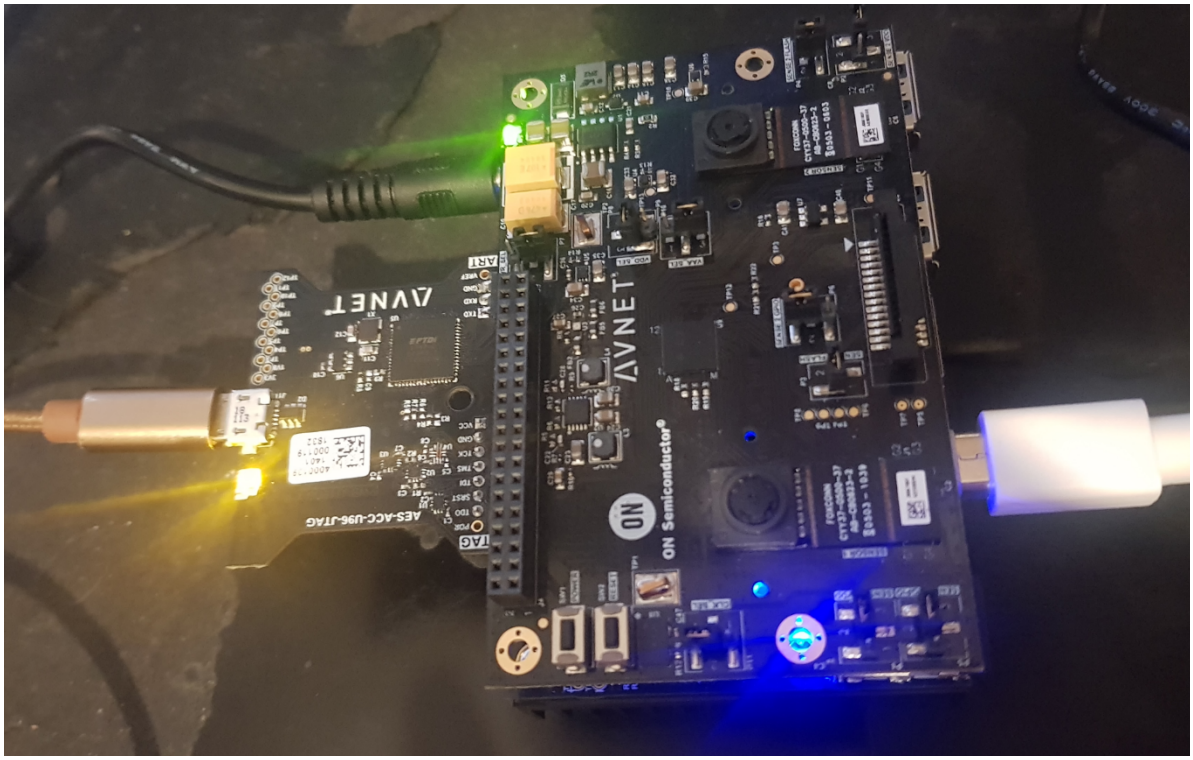
14. The final command to run is sudo sync.

```
./var/lib/rpm/installtid
./var/lib/dbus/
./var/log
./var/run
./var/volatile/
./var/lock
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/petalinux/projects/ultra96v2_dualcam_2020_1$
adiuvo@Adiuvo:~/hdl_projects/avnet_imaging/petalinux/projects/ultra96v2_dualcam_2020_1$ sudo sync
```

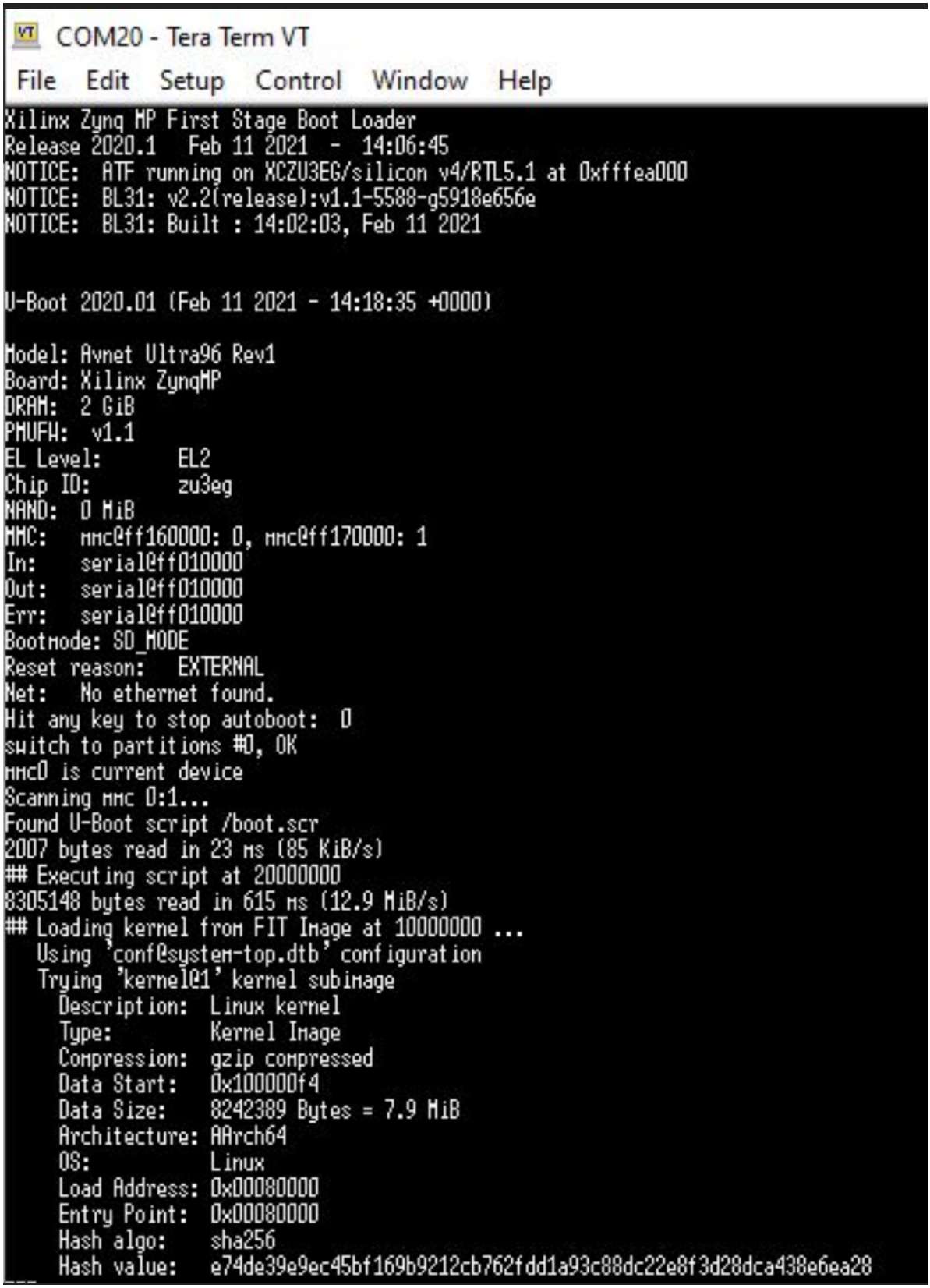
15. Safely eject the SD card.

Booting embedded Linux image

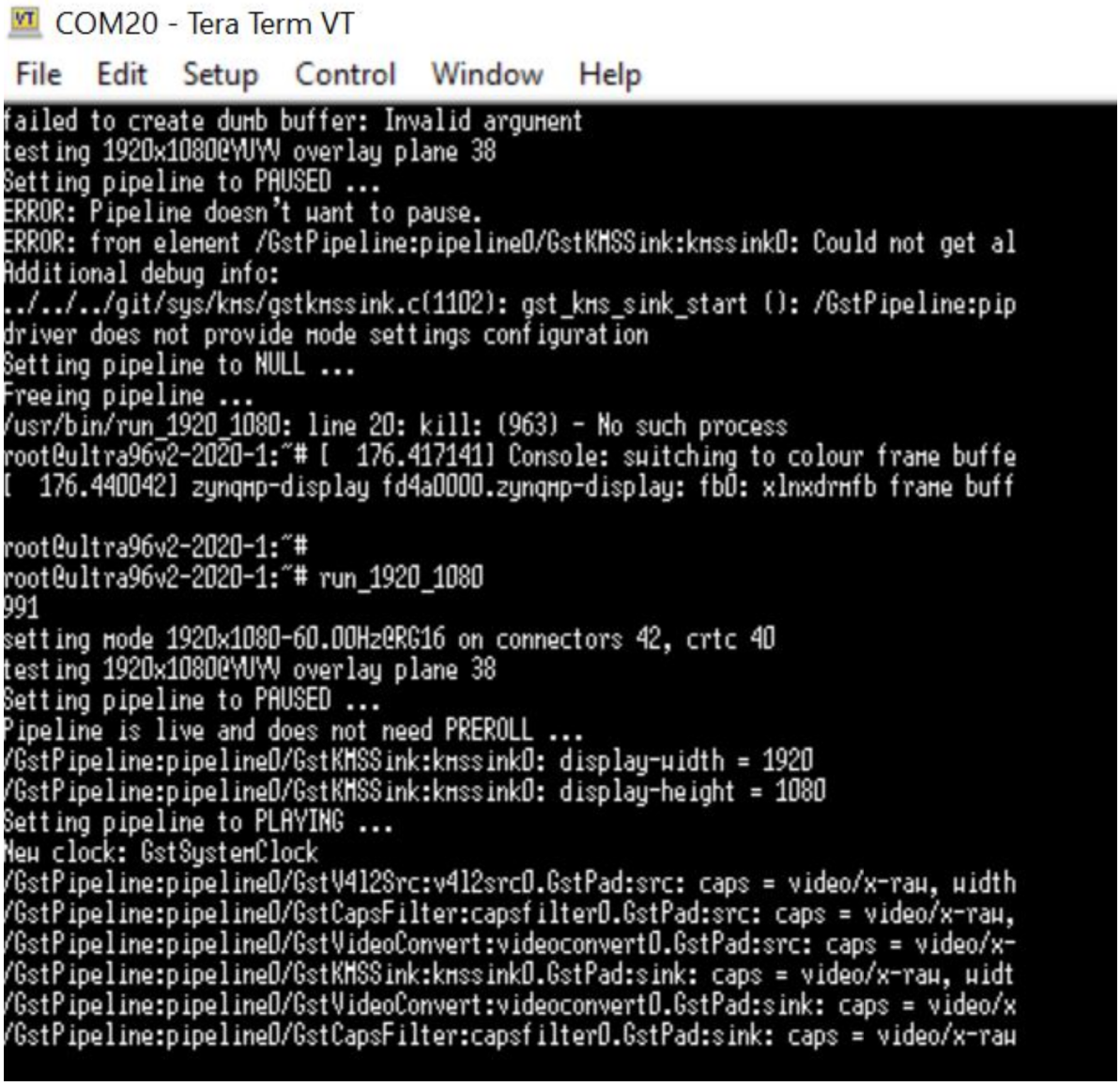
1. With the Ultra96V2 powered off, insert the SD card, connect the USB Uart breakout and power on the board. Connect the Mini Display Port connector to the display.



2. Open a terminal window with settings of 15200n1 and you will see the Linux terminal and the dmsg output as the embedded Linux OS boots.



3. Once the Embedded Linux OS has finished booting at the command prompt, enter run_1920_1080



4. An output from the two image sensors should now appear on the display running 1080P 60Hz.

IMAGE TO BE REPLACED

Conclusion

This project demonstrates how to quickly and easily leverage the Avnet Petalinux build scripts to create an embedded visions platform using embedded Linux. The embedded vision pipeline is based upon V4Linux package and GStreamer. This embedded Linux application is built upon the hardware created in the first application note.

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