Intro to Embedded Linux Part 3 - Flash SD Card

By ShawnHymel

In the previous tutorial, we walked through the process of using the Yocto Project to generate a custom embedded Linux image for the STM32MP157D-DK1 single board computer. That process generated a number of image files, which we then must copy to various partitions on an SD card in order to boot Linux.

This tutorial will walk you through the process of creating the necessary partitions on an SD card and finding which image files to copy to those partitions. See here if you would like to watch this guide in video form:

Required Hardware

I will try to explain what is happening at each step in these tutorials so that you can generalize the instructions to almost any single board computer (assuming the board is supported by the build system). However, for the demonstration, I will be using the following platform:

STM32MP157D-DK1

You will also need an SD card. The STM32MP157D-DK1 kit should come with an SD card. In addition, you will need a USB-C power supply capable of supplying 5V, 3A.

Required Software

You will need Linux for this project, as all of the tools we are using must be run in Linux. I will show steps that work in Ubuntu and Linux Mint (and likely other flavors of Debian), but you can probably get almost any Linux distro to work. LiveCD, dual-booting, Windows Subsystem for Linux (WSL), and pre-made Docker images will also likely work.

I recommend using one of the distributions listed here, as they are known to work with the Yocto Project.

The Yocto Project requires at least 50 GB of harddrive space to download and build source files.

I also recommend using a fairly modern computer with at least 4GB of RAM. While you can probably build a Linux image in a Raspberry Pi, expect it to take a very long time.

Boot Process

After Yocto finishes building your custom distribution, it should output a number of image files you can flash to non-volatile memory (such as an SD card). However, this process can be very vendor-specific.

Some vendors (and board support packages) will output a single .img file that can be flashed directly to an SD card. It will contain the necessary partitions and files needed to complete the boot process. In other cases (such as our STM32MP1), you will need to configure the partitions manually.

In most cases, booting into Linux requires several bootloader programs to run in sequence. This is known as a “boot chain” or “boot sequence.” For embedded Linux, this process will often look something like this:

ROM > First Stage Bootloader (FSBL) > Second Stage Bootloader (SSBL) > Kernel

Each stage needs to know where to find the next bootloader (in memory). The ROM bootloader is usually hardcoded in the factory and cannot be changed. It will launch the first stage bootloader, such as U-Boot SPL or TF-A, which is in charge of initializing some clocks, DDR memory, and loading the second stage bootloader.

The second stage bootloader initializes other peripherals (such as networking, USB, etc.), finalizing clocks, and loading the Linux kernel. U-Boot is a popular second stage bootloader for embedded Linux.

You will want to carefully read the documentation from your vendor to see how the boot chain works, what the image files are named for each boot process (as well as for the kernel, rootfs, etc.), and how to configure the SD card (or other non-volatile memory). If you are working with an STM32MP1 board, I highly recommend looking through this presentation.

Note: ST has deprecated the use of non-secure ("basic") bootloaders. As a result, U-Boot SPL is no longer supported. You will need to use TF-A (as the FSBL) and trusted U-Boot packaged with FIP (as the SSBL).

Flash SD Card

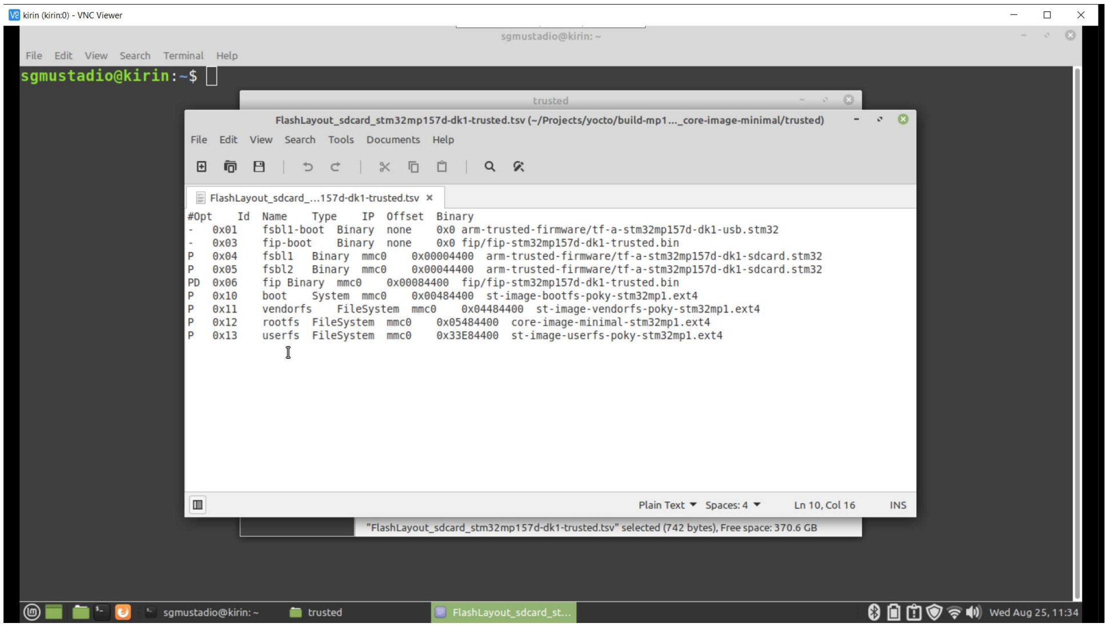
ST recommends using their STM32CubeProgrammer to flash the SD card. However, we will do things manually so you can get an idea of how to configure an SD card with the various image files.

Navigate to the output directory for your images:

Copy Code

```
cd ~/Projects/yocto/build-mp1/tmp/deploy/images/stm32mp1
```

From here, you can figure out which image files ST would use to flash an SD card by looking at the *flashlayout_core-image-minimal/trusted/FlashLayout_sdcard_stm32mp157d-dk1-trusted.tsv* file in a text editor. This will show you the name of the image files to use for the FSBL, SSBL, bootfs, and rootfs. Note that we will skip vendors and userfs partitions for now (they are not required to boot into Linux).


kirin (kirin:0) - VNC Viewer
sgmustadio@kirin: ~
File Edit View Search Terminal Help
trusted
FlashLayout_sdcard_stm32mp157d-dk1-trusted.tsv (~/Projects/yocto/build-mp1..._core-image-minimal/trusted)
File Edit View Search Tools Documents Help
FlashLayout_sdcard_...157d-dk1-trusted.tsv
Plain Text
Spaces: 4
Ln 10, Col 16
INS
sgmustadio@kirin: ~
trusted
FlashLayout_sdcard_st...
Wed Aug 25, 11:34

```
sgmustadio@kirin:~$
```

```
#Opt	Id	Name	Type	IP	Offset	Binary
-	0x01	fsbl1-boot	Binary	none	0x0	arm-trusted-firmware/tf-a-stm32mp157d-dk1-usb.stm32
-	0x03	fip-boot	Binary	none	0x0	fip/fip-stm32mp157d-dk1-trusted.bin
P	0x04	fsbl1	Binary	mmc0	0x00004400	arm-trusted-firmware/tf-a-stm32mp157d-dk1-sdcard.stm32
P	0x05	fsbl2	Binary	mmc0	0x00044400	arm-trusted-firmware/tf-a-stm32mp157d-dk1-sdcard.stm32
PD	0x06	fip	Binary	mmc0	0x00084400	fip/fip-stm32mp157d-dk1-trusted.bin
P	0x10	boot	System	mmc0	0x00484400	st-image-bootfs-poky-stm32mp1.ext4
P	0x11	vendorfs	FileSystem	mmc0	0x04484400	st-image-vendorfs-poky-stm32mp1.ext4
P	0x12	rootfs	FileSystem	mmc0	0x05484400	core-image-minimal-stm32mp1.ext4
P	0x13	userfs	FileSystem	mmc0	0x33E84400	st-image-userfs-poky-stm32mp1.ext4
```

"FlashLayout_sdcard_stm32mp157d-dk1-trusted.tsv" selected (742 bytes), Free space: 370.6 GB

Plug an SD card into your host computer and figure out its device file location:

Copy Code

```
lsblk
```

For me, the SD card raw device file could be found at /dev/mmcblk2, so I will use that in the following steps.

Make sure to unmount any partitions that were automounted when you plugged in the SD card (e.g. using umount or through the GUI).

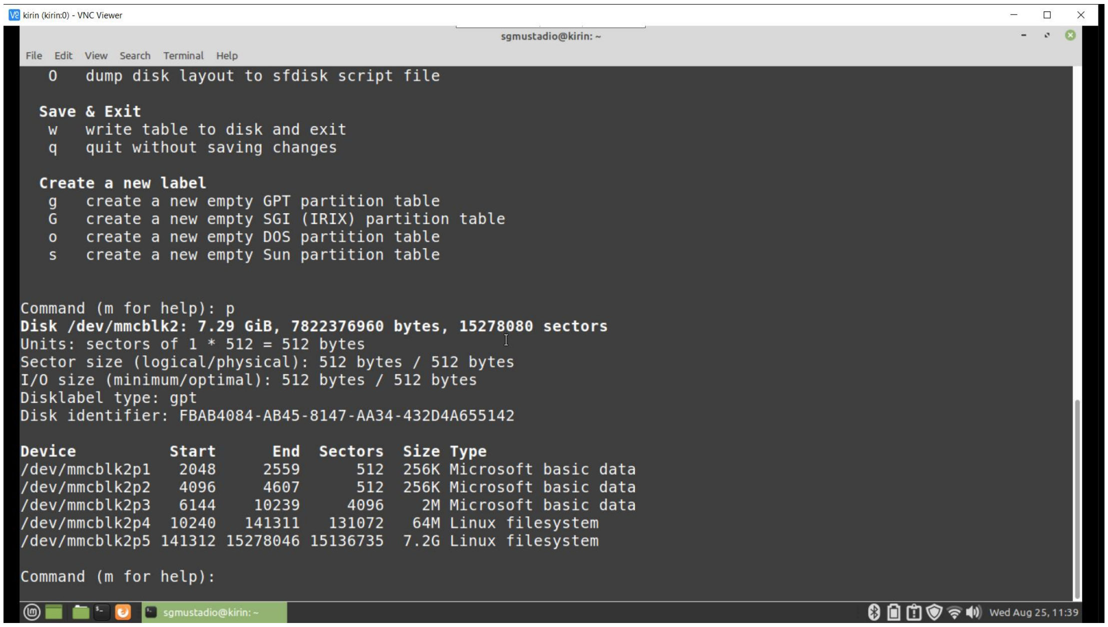
Next, we will format the disk to contain the necessary partitions (change mmcblk2 to wherever your SD card can be found):

Copy Code

```
sudo fdisk /dev/mmcblk2
```

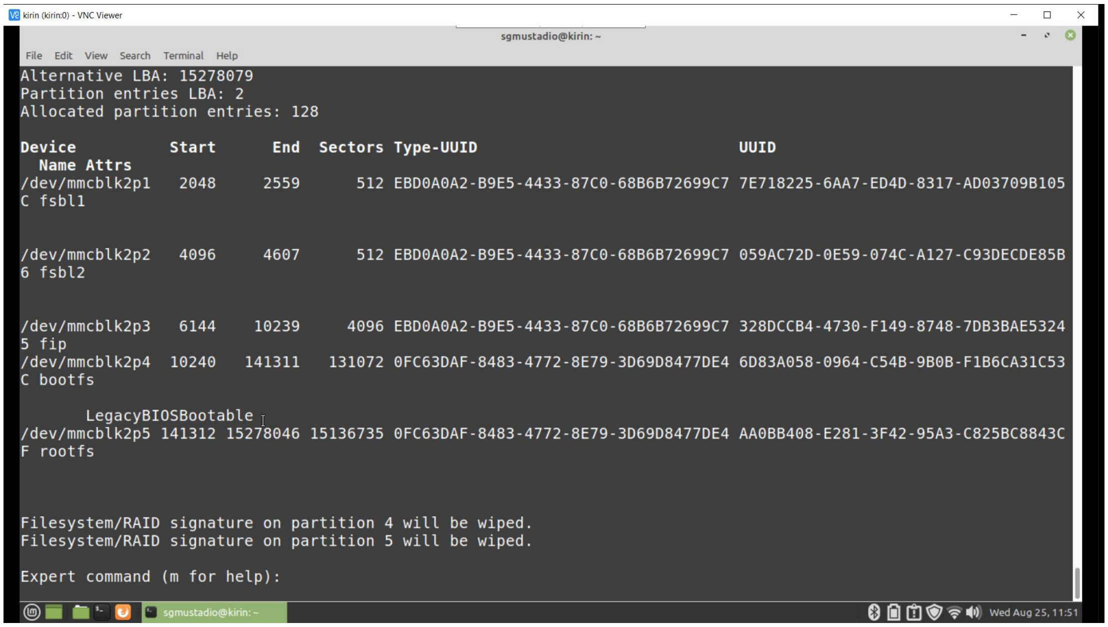
In fdisk, perform the following actions to format the card:

- ‘p’ view the partitions
- ‘d’ to delete a partition
    - Select one of the partitions
    - Repeat this process until all partitions have been deleted
- If your SD card is not a GPT layout, you will need to change it to GPT.
    - Type ‘p’ and look at “Disklabel type.” It should say “gpt” (many SD cards come pre-formatted with MBR, which will show up as “dos” in this step).
    - ‘g’ to change the layout to GPT
- ‘n’ for new partition
    - Press ‘enter’ to choose the default partition number (will start at ‘1’)
    - Press ‘enter’ to let fdisk choose the default starting sector (you want the sectors to align with the natural boundaries, otherwise, your partition sizes might be different from what you enter in the next step)
    - Enter “+256KiB” for the size of the sector
    - ‘t’ to change the partition type
    - ‘11’ for “Microsoft basic data” (used to hold FAT16 and FAT32 partitions)
- This creates the first copy of the FSBL partition. Repeat this process to create 5 total partitions:
    - Partition 1: 256 KiB, (11) Microsoft basic data
    - Partition 2: 256 KiB, (11) Microsoft basic data
    - Partition 3: 2 MiB, (11) Microsoft basic data
    - Partition 4: 64 MiB, (20) Linux filesystem
    - Partition 5: <rest of SD card space>, (20) LInux filesystem


kirin (kirin:0) - VNC Viewer
sgmustadio@kirin: ~
File Edit View Search Terminal Help
sgmustadio@kirin: ~
Wed Aug 25, 11:39

```
   O   dump disk layout to sfdisk script file

  Save & Exit
   w   write table to disk and exit
   q   quit without saving changes

  Create a new label
   g   create a new empty GPT partition table
   G   create a new empty SGI (IRIX) partition table
   o   create a new empty DOS partition table
   s   create a new empty Sun partition table


Command (m for help): p
Disk /dev/mmcblk2: 7.29 GiB, 7822376960 bytes, 15278080 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: gpt
Disk identifier: FBAB4084-AB45-8147-AA34-432D4A655142

Device          Start      End  Sectors  Size Type
/dev/mmcblk2p1   2048     2559      512  256K Microsoft basic data
/dev/mmcblk2p2   4096     4607      512  256K Microsoft basic data
/dev/mmcblk2p3   6144    10239     4096    2M Microsoft basic data
/dev/mmcblk2p4  10240   141311   131072   64M Linux filesystem
/dev/mmcblk2p5 141312 15278046 15136735  7.2G Linux filesystem

Command (m for help):
```

- ‘x’ to go into expert mode in fdisk
- ‘n’ to assign a label to a partition. Name the partitions as follows:
    - Partition 1: fsbl1
    - Partition 2: fsbl2
    - Partition 3: fip
    - Partition 4: bootfs
    - Partition 5: rootfs
- ‘A’ to mark a partition as legacy BIOS bootable
- ‘4’ to mark the bootfs partition as bootable
- ‘p’ to view the partition info. The Partition UUIDs and partition sizes might be different from mine.



kirin (kirin:0) - VNC Viewer
sgmustadio@kirin: ~
File Edit View Search Terminal Help
sgmustadio@kirin: ~
Wed Aug 25, 11:51

```
Alternative LBA: 15278079
Partition entries LBA: 2
Allocated partition entries: 128

Device          Start      End  Sectors Type-UUID                            UUID
  Name Attrs
/dev/mmcblk2p1   2048     2559      512 EBD0A0A2-B9E5-4433-87C0-68B6B72699C7 7E718225-6AA7-ED4D-8317-AD03709B105
C fsbl1


/dev/mmcblk2p2   4096     4607      512 EBD0A0A2-B9E5-4433-87C0-68B6B72699C7 059AC72D-0E59-074C-A127-C93DECDE85B
6 fsbl2


/dev/mmcblk2p3   6144    10239     4096 EBD0A0A2-B9E5-4433-87C0-68B6B72699C7 328DCCB4-4730-F149-8748-7DB3BAE5324
5 fip
/dev/mmcblk2p4  10240   141311   131072 0FC63DAF-8483-4772-8E79-3D69D8477DE4 6D83A058-0964-C54B-9B0B-F1B6CA31C53
C bootfs

       LegacyBIOSBootable
/dev/mmcblk2p5 141312 15278046 15136735 0FC63DAF-8483-4772-8E79-3D69D8477DE4 AA0BB408-E281-3F42-95A3-C825BC8843C
F rootfs



Filesystem/RAID signature on partition 4 will be wiped.
Filesystem/RAID signature on partition 5 will be wiped.

Expert command (m for help):
```

- 'r' to return to the main menu
- 'w' write changes to the card and exit

You can confirm that the changes were made by entering the 'lsblk' command again.

Next, we need to copy the image files to the partitions. Once again, change "mmcblk2" to whatever drive file your host computer lists for the SD card:

Copy Code

```
sudo dd if=arm-trusted-firmware/tf-a-stm32mp157d-dk1-sdcard.stm32 of=/dev/mmcblk2p1
sudo dd if=arm-trusted-firmware/tf-a-stm32mp157d-dk1-sdcard.stm32 of=/dev/mmcblk2p2
sudo dd if=fip/fip-stm32mp157d-dk1-trusted.bin of=/dev/mmcblk2p3
sudo dd if=st-image-bootfs-poky-stm32mp1.ext4 of=/dev/mmcblk2p4 bs=1M
sudo dd if=core-image-minimal-stm32mp1.ext4 of=/dev/mmcblk2p5 bs=1M
```

Before we try booting, we need to make one final change. The STM32CubeProgrammer will rename the partition UUIDs (PARTUUIDs) to specific values. U-Boot will look for a particular PARTUUID when trying to mount the root filesystem (rootfs). You can either use fdisk (in expert mode) to change the PARTUUID of rootfs to e91c4e10-16e6-4c0e-bd0e-77becf4a3582, or you can modify the bootfs configuration file to point to the rootfs partition (e.g. mmcblk0p5).

To do the latter, mount the bootfs partition (using the mount command or through your host Linux GUI). Edit *bootfs/mmc0_extlinux/extlinux.conf* with superuser privileges. For example:

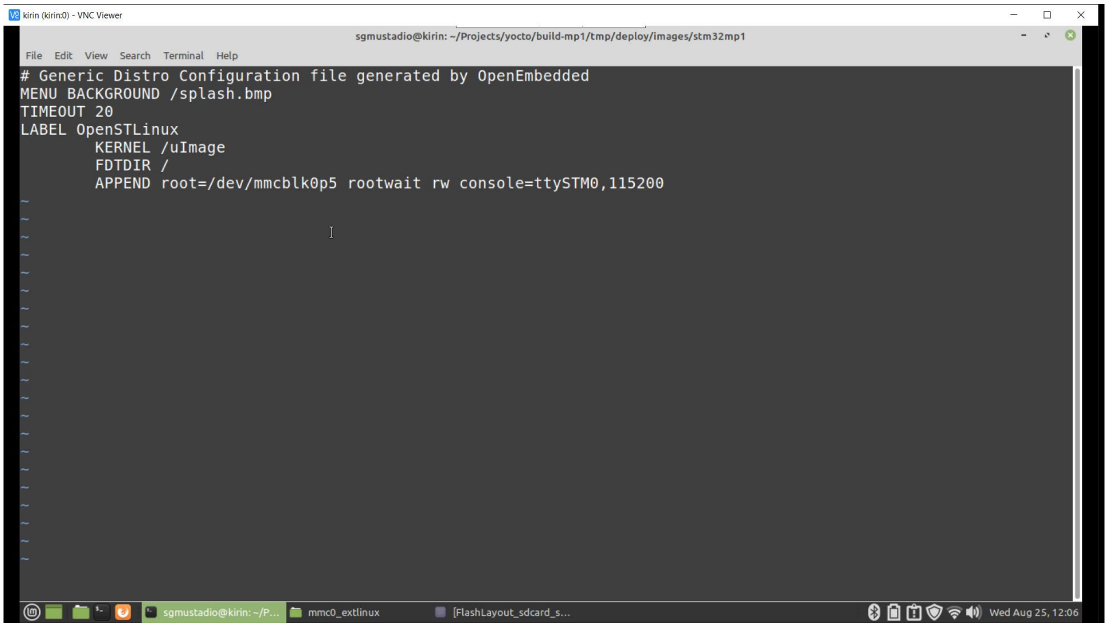
Copy Code

```
sudo vi /media/<username>/bootfs/mmc0_extlinux/extlinux.conf
```

Change the APPEND line to the following:

Copy Code

```
APPEND root=/dev/mmcblk0p5 rootwait rw console=ttySTM0,115200
```



```
# Generic Distro Configuration file generated by OpenEmbedded
MENU BACKGROUND /splash.bmp
TIMEOUT 20
LABEL OpenSTLinux
        KERNEL /uImage
        FDTDIR /
        APPEND root=/dev/mmcblk0p5 rootwait rw console=ttySTM0,115200
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
```

Note that mmcblk0 is the device file for the SD card according to U-Boot. Partition 5 (p5) is the location of rootfs. If you put rootfs on a different partition number, you will likely need to change this.

Save and exit. Sync the SD card with:

Copy Code

```
sync
```

Unmount the bootfs partition (with ‘umount’ or using the GUI). Remove the SD card.

Boot Into Linux

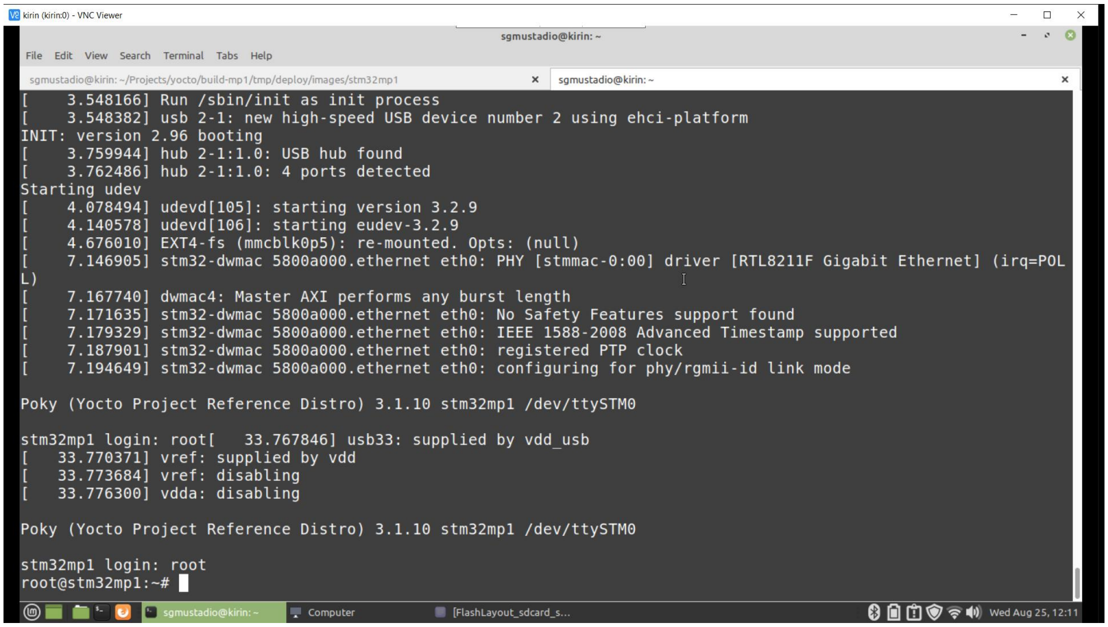
Plug the SD card into the STM32MP157D-DK1 board. Connect a USB micro cable from your host computer to the ST-LINK (CN11) port on the board. On your host computer, enter the following:

Copy Code

```
picocom -b 115200 /dev/ttyACM0
```

Note that ACM0 might be different depending on your particular flavor of Linux and any other attached hardware you might have. It should point to the device file for your USB serial port (likely a CDC class) that is connected to the STM32MP157D-DK1.

If everything works, you should see the FSBL (TF-A) post a few lines to the console followed by the SSBL (U-Boot). U-Boot will launch the kernel, and after a few seconds, you should be presented with a login prompt. Enter “root” (no password) to gain access to Linux.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File Edit View Search Terminal Tabs Help
sgmustadio@kirin: ~/Projects/yocto/build-mp1/tmp/deploy/images/stm32mp1
sgmustadio@kirin: ~
sgmustadio@kirin: ~
Computer
[FlashLayout_sdcard_s...
Wed Aug 25, 12:11

```
[    3.548166] Run /sbin/init as init process
[    3.548382] usb 2-1: new high-speed USB device number 2 using ehci-platform
INIT: version 2.96 booting
[    3.759944] hub 2-1:1.0: USB hub found
[    3.762486] hub 2-1:1.0: 4 ports detected
Starting udev
[    4.078494] udevd[105]: starting version 3.2.9
[    4.140578] udevd[106]: starting eudev-3.2.9
[    4.676010] EXT4-fs (mmcblk0p5): re-mounted. Opts: (null)
[    7.146905] stm32-dwmac 5800a000.ethernet eth0: PHY [stmmac-0:00] driver [RTL8211F Gigabit Ethernet] (irq=POL
L)
[    7.167740] dwmac4: Master AXI performs any burst length
[    7.171635] stm32-dwmac 5800a000.ethernet eth0: No Safety Features support found
[    7.179329] stm32-dwmac 5800a000.ethernet eth0: IEEE 1588-2008 Advanced Timestamp supported
[    7.187901] stm32-dwmac 5800a000.ethernet eth0: registered PTP clock
[    7.194649] stm32-dwmac 5800a000.ethernet eth0: configuring for phy/rgmii-id link mode

Poky (Yocto Project Reference Distro) 3.1.10 stm32mp1 /dev/ttySTM0

stm32mp1 login: root[   33.767846] usb33: supplied by vdd_usb
[   33.770371] vref: supplied by vdd
[   33.773684] vref: disabling
[   33.776300] vdda: disabling

Poky (Yocto Project Reference Distro) 3.1.10 stm32mp1 /dev/ttySTM0

stm32mp1 login: root
root@stm32mp1:~# 
```

You might see a few messages from the kernel arrive after you receive the prompt. You can just ignore them for now.