Zynq™ UltraScale+™ MPSoC (Kria KV260) Arch Linux

Introduction

The Zynq™ UltraScale+™ MPSoC (Kria KV260) Arch Linux project is designed to provide a versatile and customizable development environment tailored for the Zynq UltraScale+ MPSoC, particularly the Kria KV260 board. The primary aim of this project is to enable users to seamlessly deploy Arch Linux ARM on the Kria KV260, facilitating both FPGA configuration and Linux system development. By integrating Arch Linux ARM, renowned for its flexibility and broad hardware support, with the robust capabilities of the Zynq UltraScale+ MPSoC, this project offers a comprehensive platform for a wide range of embedded applications. Emphasizing configurability and adherence to best practices in FPGA and Linux development, this project empowers users to harness the full potential of the Kria KV260 board.

Furthermore, the project extends its utility by offering the possibility of remote development. With remote access capabilities enabled, developers can seamlessly collaborate and work on the Kria KV260 board from any location. By leveraging SSH connections and tools like Visual Studio Code's Remote Development extension pack, developers can maintain productivity and flexibility, even when physically distant from the development hardware.

Ultimately, this project serves as a valuable resource for developers seeking to leverage the power of Arch Linux ARM in conjunction with the advanced features of the Zynq UltraScale+ MPSoC for their embedded systems projects, while also enabling efficient remote development workflows.

Overview

The project aims to create a robust and customizable development environment for the Zynq UltraScale+ MPSoC, enabling users to deploy Arch Linux ARM on the Kria KV260 board. This environment facilitates FPGA configuration and Linux system development for a wide range of embedded applications. The project is based on the Kria KV260 and PetaLinux Tools 2023.2. For detailed information and updates refer to the official documentation and the specific hardware platform:

- Vivado Design Suite User Guide
- PetaLinux Tools Documentation: Reference Guide (UG1144)
- Zynq UltraScale+ MPSoC - Wiki
- Kria KV260 Vision AI Starter Kit Data Sheet (DS986)
- Kria KV260 Vision AI Starter Kit User Guide (UG1089)

Additionally, the guide emphasizes configuration flexibility, and adherence to best practices for FPGA and Linux development. When Arch Linux ARM is installed on the Zynq UltraScale+ MPSoC, its flexibility and customization capabilities make it an ideal environment for FPGA development. As a general-purpose Linux distribution, it accommodates diverse applications, ensuring a continuous influx of the latest updates. The broad hardware support inherent in Arch Linux ARM extends seamlessly to the specific requirements of the Zynq UltraScale+ MPSoC, making it well-suited for embedded systems development on this platform.

FPGA Project (Kria KV260)

Requirements

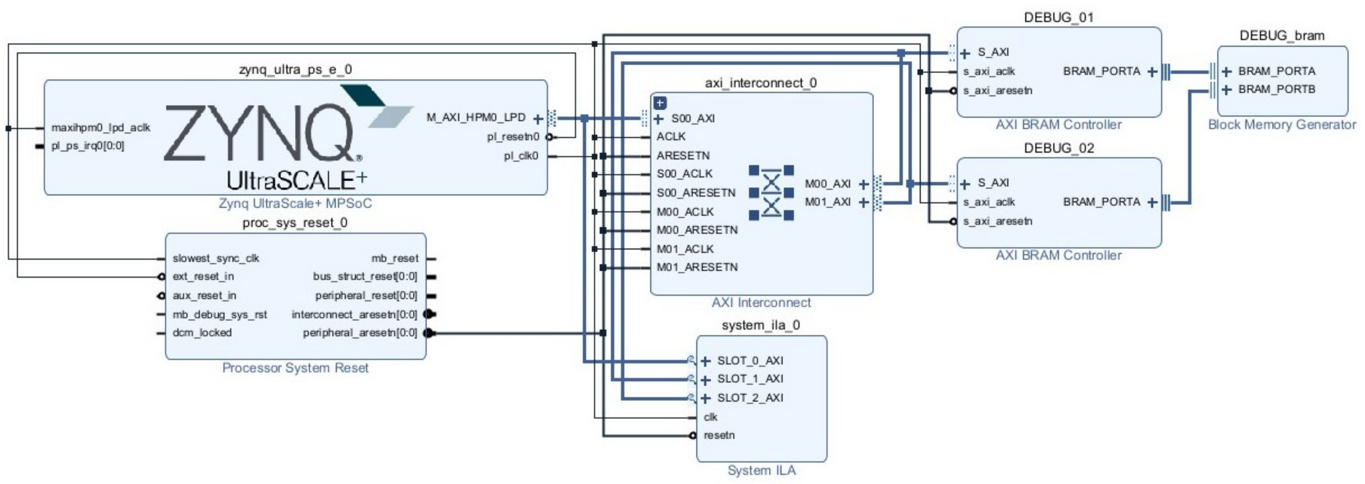
- Vivado ML Edition 2023.2

FPGA Design

A new project is created with the Vivado New Project Wizard. After the project is created, a block design is created with the Vivado IP Integrator. The block design consists of the following IP blocks:

- Zynq UltraScale+ MPSoC (set up in accordance with the requirements. The file Zynq UltraScale+ MPSoC LPD.tcl with presets for the Zynq UltraScale+ MPSoC can be found in the folder **Kria KV260**)
- Processor System Reset
- AXI Interconnect
- AXI BRAM Controllers
- Block Memory Generator
- System ILA (connected to the M_AXI_HPM0_LPD interface)

See the following image for the block design:



This is a simple example of an FPGA design to create a Petalinux project based on the Kria KV260.

After the block design has been created, the design is validated, synthesized and implemented and a bitstream is generated. Then it is required to export hardware, including bitstream *<project_name>.xsa*. The XSA file is used to create a Petalinux project. The XSA file *kria_kv260_bd_wrapper.xsa* is located in the folder **Kria KV260**.

When the XSA file has been exported successfully, a Petalinux project is ready to be created.

Petalinux Project

Requirements

- PetaLinux Tools Documentation: Reference Guide (UG1144)
- Ubuntu 22.04.2 LTS (virtual machine is preferred)
- PetaLinux Tools 2023.2 (installed according to the documentation)

Upgrade PetaLinux Tools

After the PetaLinux Tools are installed, it is necessary to upgrade the PetaLinux Tools to the latest version. The following commands are executed:

```
petalinux-upgrade -u http://petalinux.xilinx.com/sswreleases/rel-
v2023/sdkupdate/2023.2/ -p "aarch64" --wget-args "--wait 1 -nH --cut-dirs=4"
```

Creating a Petalinux Project from XSA

An empty project is created with the following command:

```
petalinux-create --type project --template zynqMP --name <project name>
cd <project name>
```

Configuring a Petalinux Project

After the project is created, the XSA file is imported with the following command:

```
petalinux-config --get-hw-description ~/<file name>.xsa
```

After the XSA file has been imported successfully, the PetaLinux system configuration is opened. The following settings are changed:

```
→ Subsystem AUTO Hardware Settings  --->
    Ethernet Settings  --->
        [*] Randomise MAC address

→ FPGA Manager --->
    [*] Fpga Manager

→ Image Packaging Configuration --->
    Root filesystem type (INITRAMFS) --->
        (X) INITRAMFS
    (petalinux-initramfs-image) INITRAMFS/INITRD Image name
        petalinux-initramfs-image
```

Also, if needed, it is possible to implement changes to the kernel using the following command:

```
petalinux-config -c kernel
```

If any changes are needed to the rootfs, it is possible to implement the changes using the following command:

```
petalinux-config -c rootfs
```

Creating a Petalinux Project from BSP

Create a Petalinux project from the BSP file with the following command:

```
petalinux-create --type project --source <path to the BSP file> --name <project
name>
cd <project name>
```

Building a Petalinux Project

After the settings have been changed, the PetaLinux system configuration is closed and the project is built with the following command (Internet connection is required for the build):

```
petalinux-build
```

Packaging a Petalinux Project

After the project is built, the project is packaged with the following command:

```
petalinux-package --boot --format BIN --fsbl images/linux/zynqmp_fsbl.elf --u-boot
images/linux/u-boot.elf --pmufw images/linux/pmufw.elf --fpga
images/linux/system.bit --force
```

Preparing the Arch Linux ARM rootfs

The Arch Linux ARM rootfs is prepared with the following commands:

- Download the latest Arch Linux ARM to the home directory:

  ```
  wget http://os.archlinuxarm.org/os/ArchLinuxARM-aarch64-latest.tar.gz
  ```

Create WIC image

After the project is built, it is possible to create a WIC image. The following command is executed:

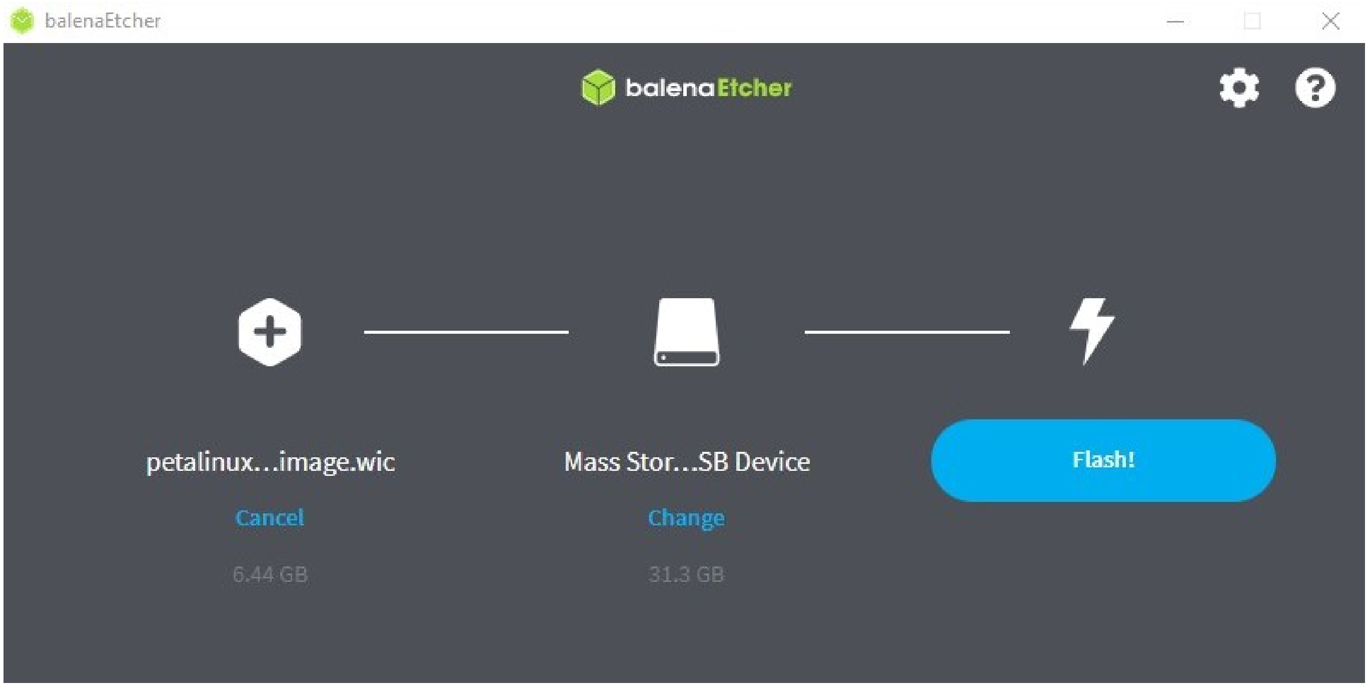
```
petalinux-package --wic --bootfiles "BOOT.BIN boot.scr Image image.ub
ramdisk.cpio.gz.u-boot" --rootfs-file ~/ArchLinuxARM-aarch64-latest.tar.gz --
outdir ~/<project name>/images
```

After the WIC image is created, the WIC image is located in the folder **images**.

Flash an SD card with WIC image

The WIC image is written to an SD card using balenaEtcher.

See the following image for an example of writing the WIC image to an SD card:



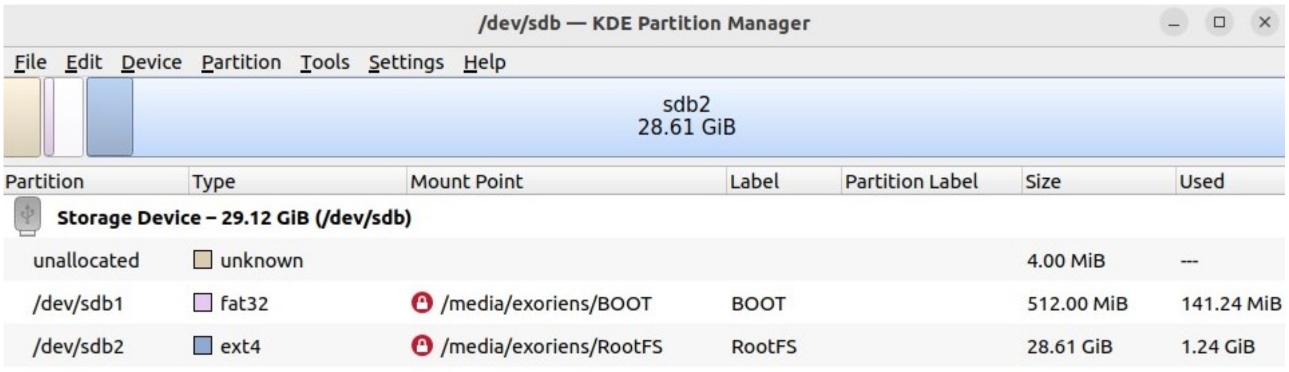
Preparing an SD card manually

Here are the steps to prepare an SD card for the PetaLinux SD card ext file system boot.

The SD card is formatted with two partitions using a partition manager. The first partition should be at least 500 MB in size and formatted as a FAT32 file system. Ensure that there is 4 MB of free space preceding the partition. The first partition contains the boot loader, device tree, and kernel images. The second partition should be formatted as an ext4 files system and can take up the remaining space on the SD card. This partition stores the system root file system.

1. Label the first partition as BOOT.
2. Label the second partition as RootFS.

   See the following image for an example of the SD card partition:

   
   /dev/sdb — KDE Partition Manager
File Edit Device Partition Tools Settings Help
sdb2
28.61 GiB

Partition	Type	Mount Point	Label	Partition Label	Size	Used
Storage Device – 29.12 GiB (/dev/sdb)						
unallocated	unknown				4.00 MiB	---
/dev/sdb1	fat32	/media/exoriens/BOOT	BOOT		512.00 MiB	141.24 MiB
/dev/sdb2	ext4	/media/exoriens/RootFS	RootFS		28.61 GiB	1.24 GiB

3. Copy the files as follows:
   - FAT32 partition: BOOT.BIN, boot.scr, Image, image.ub, and ramdisk.cpio.gz.u-boot
   - EXT4 partition: extract the Arch Linux ARM rootfs to the root of the partition with the following command:

```
sudo tar -xfvp ~/ArchLinuxARM-aarch64-latest.tar.gz -C
/media/<username>/RootFS
```

After the SD card is prepared, it is possible to boot the Kria KV260 board with the SD card.

Booting the Kria KV260 board

The Kria KV260 board is booted with the SD card. The SD card is inserted into the SD card slot on the Kria KV260 board. The board is powered on and the boot process is started. The boot process is shown on the serial console such as PuTTY. After the first boot of the Arch Linux ARM, the following will be displayed on the serial console:

```
Arch Linux 6.1.30-xilinx-v2023.2 (ttyPS0)
alarm login:
```

The default username is **alarm** and the default password is **alarm**.

To setup the Arch Linux ARM through SSH connection, connect to the Kria KV260 board using the following command:

```
ssh alarm@alarm
```

After the login, similar information will be displayed on the console:

```
Last login: Tue Mar 19 03:29:29 2024 from fe80::30cf:4b52:1763:9d82%eth0
[alarm@alarm ~]$
```

Setting up the Arch Linux ARM

After the first boot, it is necessary to go to the root (the password is **root**). The following commands are executed:

```
su
```

Initialize the pacman keyring and populate the Arch Linux ARM package signing keys:

```
pacman-key --init
pacman-key --populate
```

Then update the system and install the sudo package:

```
pacman -Syu
pacman -S sudo
```

After the updates and installation of the sudo package, add a new user. Use the following command:

```
useradd -m <username>
```

Set a password for the new user:

```
passwd <username>
```

Then add a new user to the sudoers file. Open the sudoers file with the following command:

```
nano /etc/sudoers
```

Add the following line after the root line (root ALL=(ALL:ALL) ALL):

```
<username> ALL=(ALL:ALL) ALL
```

Save (CTRL + S) and exit (CTRL + X) the file.

Also, it is possible to change the host name. Open the hostname file with the following command:

```
nano /etc/hostname
```

Change the host name to the desired one. Save (CTRL + S) and exit (CTRL + X) the file and **reboot**.

```
reboot
```

Login with your new user name and password. In my case, the following is displayed:

```
[vtuser@kria-kv260 ~]$
```

Generating locales

List the available locales with the following command:

```
locale -a
```

Generate the desired locale with the following command:

```
sudo nano /etc/locale.gen
```

Uncomment the desired locale. For example:

```
...
#en_SG ISO-8859-1
en_US.UTF-8 UTF-8
#en_US ISO-8859-1
...
```

Save (CTRL + S) and exit (CTRL + X) the file. Then generate the locale with the following command:

```
sudo locale-gen
```

Reboot the system with the following command:

```
sudo reboot
```

Installing packages

After the login, it is necessary to install the following packages. For example:

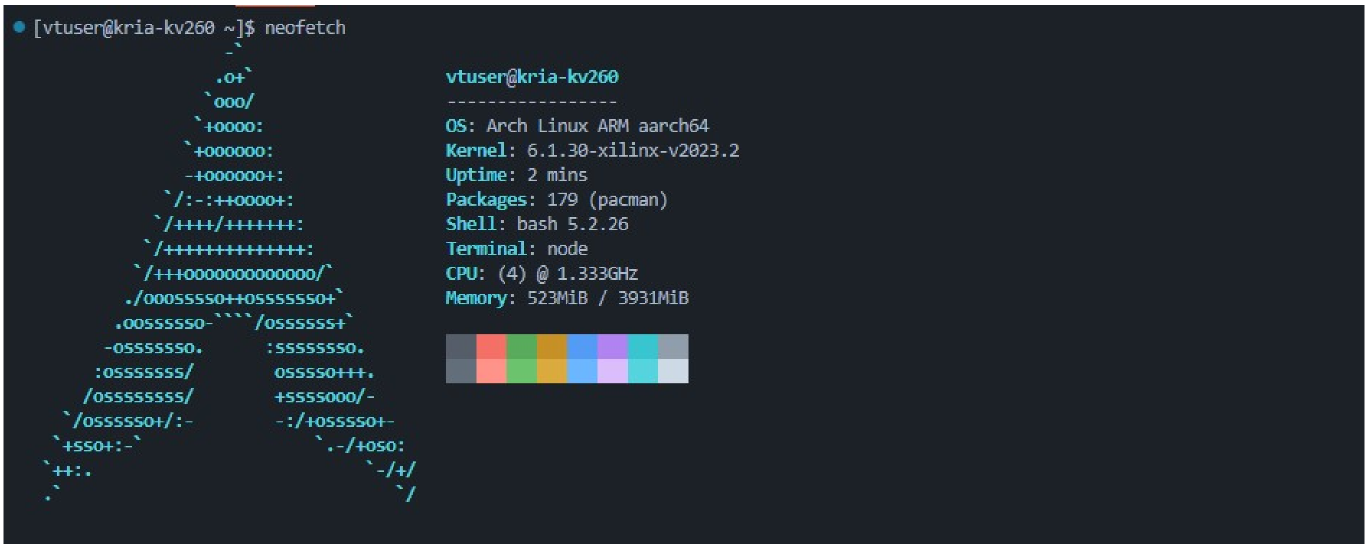
```
sudo pacman -S gcc python3 neofetch wget htop
```

System information

Now the Arch Linux ARM is ready to use. Write the following command to see the system information:

```
neofetch
```

You will see the following information:



```
● [vtuser@kria-kv260 ~]$ neofetch
                   -`
                  .o+`                   vtuser@kria-kv260
                 `ooo/                   -----------------
                `+oooo:                  OS: Arch Linux ARM aarch64
               `+oooooo:                 Kernel: 6.1.30-xilinx-v2023.2
               -+oooooo+:                Uptime: 2 mins
             `/:-:++oooo+:               Packages: 179 (pacman)
            `/++++/+++++++:              Shell: bash 5.2.26
           `/++++++++++++++:             Terminal: node
          `/+++ooooooooooooo/`           CPU: (4) @ 1.333GHz
         ./ooosssso++osssssso+`          Memory: 523MiB / 3931MiB
        .oossssso-````/ossssss+`
       -osssssso.      :ssssssso.
      :osssssss/        osssso+++.
     /ossssssss/        +ssssooo/-
   `/ossssso+/:-        -:/+osssso+-
  `+sso+:-`                 `.-/+oso:
 `++:.                           `-/+/
 .`                                 `/
```

Installing fpgautil

The fpgautil package is required to load the FPGA bitstream. To install the fpgautil, perform the following steps:

- Copy the fpgautil folder to the home directory using SFTP.
- Go to the fpgautil folder and execute the following commands:

  ```
  cd fpgautil
  ./install.sh
  ```

After the successful installation, the following is displayed:

```
Files copied successfully from /home/vtuser/fpgautil to /usr/bin
fpgautil is now executable in /usr/bin
```

Configuring the FPGA

Create a folder for the FPGA bitstream. For example:

```
mkdir Bitstreams
```

Copy the bitstream to the folder using SFTP.

After the installation of the fpgautil, it is possible to configure the FPGA. The following commands are executed:

```
sudo fpgautil -b ~/Bitstreams/<bitstream>.bit
```

After the successful configuration, the following is displayed:

```
Time taken to load BIN is 153.000000 Milli Seconds
BIN FILE loaded through FPGA manager successfully
```

Now the FPGA is configured and ready to use.

Remote access to the Kria KV260 board

Remote access using SSH

To access the Kria KV260 board remotely, it is necessary to know the IP address of the board. To find the IP address, the following command is executed:

```
ifconfig
```

If ifconfig is not installed, it is possible to install it with the following command:

```
sudo pacman -S net-tools
```

After the IP address is found, it is possible to access the board remotely using SSH. For example:

```
ssh <username>@<ip_address>
or
ssh <username>@<hostname>
```

Remote development using Visual Studio Code

To develop remotely using Visual Studio Code, it is necessary to install the Remote Development extension pack. After the extension pack is installed, it is possible to connect to the Kria KV260 board using SSH. For example:

```
Open Remote Window -> Remote SSH -> Connect to Host...
or
shift + ctrl + p -> Remote-SSH: Connect to Host...
```

When connecting to the host, you will be asked to enter the password. After the password is entered, the connection is established. Once the connection has been established, it is possible to open the folder on the Kria KV260 board.

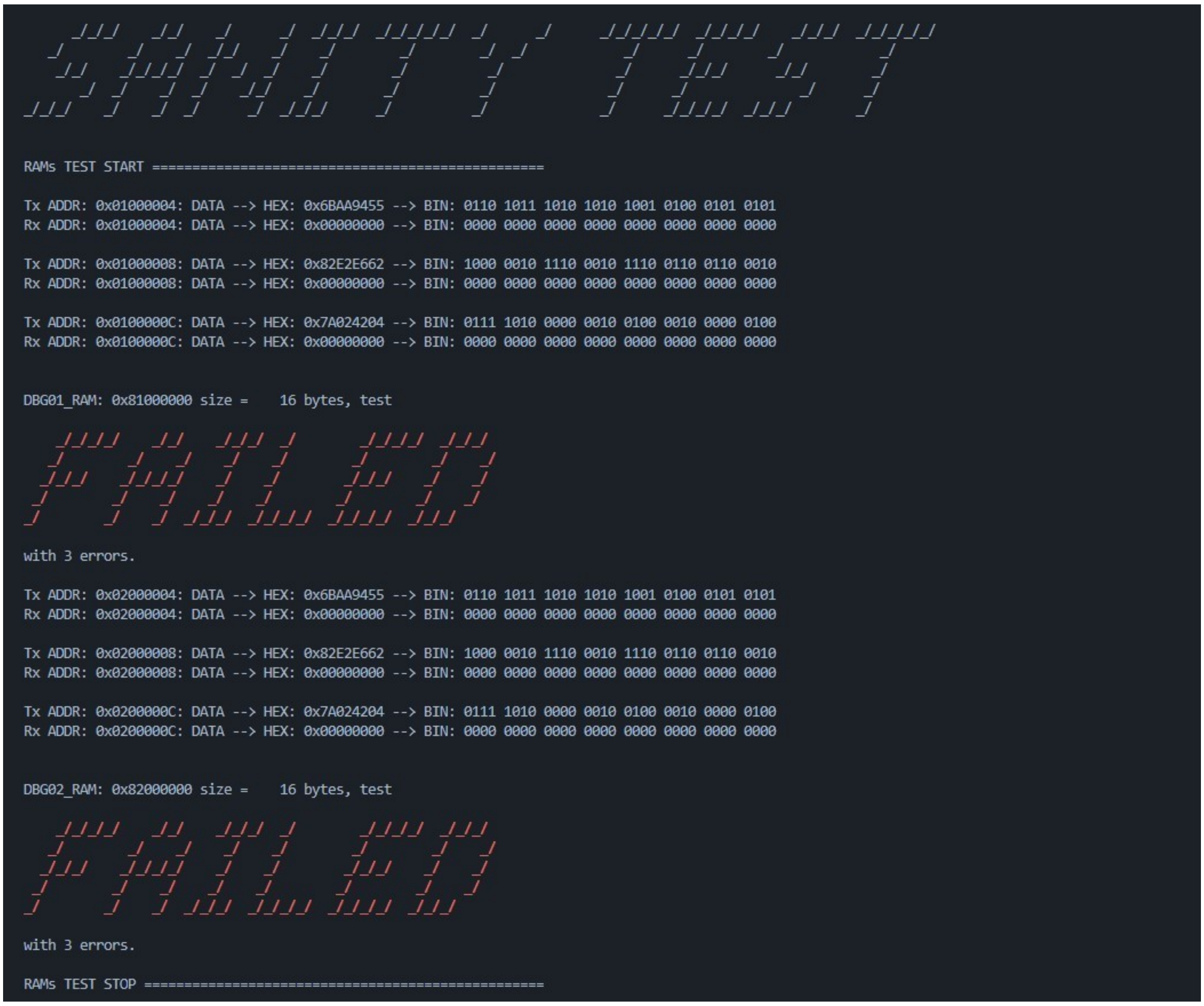
Testing the Kria KV260 board

Sanity test

Sanity test is a simple test to check the functionality of the FPGA. Copy the TestCases folder to the home directory using SFTP. Execute the following command to run the test:

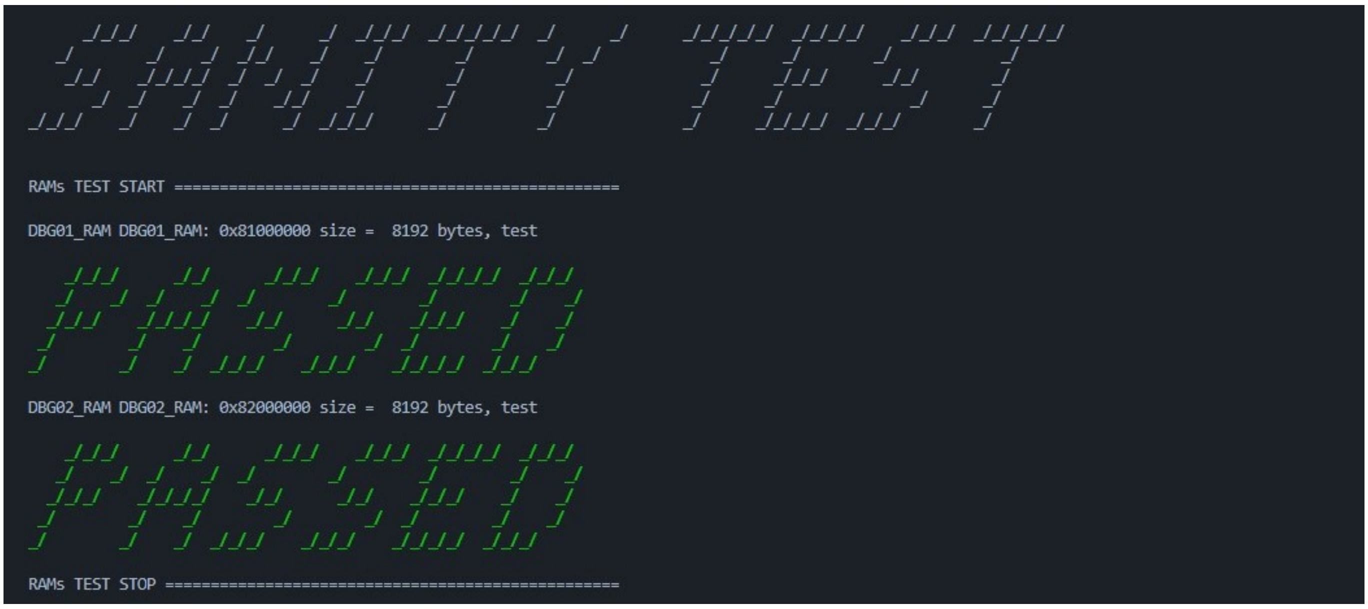
```
sudo python3 ~/TestCases/sanity_test/main.py
```

If the test is not successful, a similar message is displayed:



```
    _/_/_/    _/_/    _/      _/  _/_/_/  _/_/_/_/_/  _/      _/      _/_/_/_/_/  _/_/_/_/    _/_/_/  _/_/_/_/_/
 _/        _/    _/  _/_/    _/    _/        _/        _/  _/            _/      _/        _/            _/
  _/_/    _/_/_/_/  _/  _/  _/    _/        _/          _/              _/      _/_/_/      _/_/        _/
     _/  _/    _/  _/    _/_/    _/        _/          _/              _/      _/              _/      _/
_/_/_/    _/    _/  _/      _/  _/_/_/      _/          _/              _/      _/_/_/_/  _/_/_/        _/


RAMs TEST START ==================================================

Tx ADDR: 0x01000004: DATA --> HEX: 0x6BAA9455 --> BIN: 0110 1011 1010 1010 1001 0100 0101 0101
Rx ADDR: 0x01000004: DATA --> HEX: 0x00000000 --> BIN: 0000 0000 0000 0000 0000 0000 0000 0000

Tx ADDR: 0x01000008: DATA --> HEX: 0x82E2E662 --> BIN: 1000 0010 1110 0010 1110 0110 0110 0010
Rx ADDR: 0x01000008: DATA --> HEX: 0x00000000 --> BIN: 0000 0000 0000 0000 0000 0000 0000 0000

Tx ADDR: 0x0100000C: DATA --> HEX: 0x7A024204 --> BIN: 0111 1010 0000 0010 0100 0010 0000 0100
Rx ADDR: 0x0100000C: DATA --> HEX: 0x00000000 --> BIN: 0000 0000 0000 0000 0000 0000 0000 0000


DBG01_RAM: 0x81000000 size =    16 bytes, test

    _/_/_/_/    _/_/    _/_/_/  _/        _/_/_/_/  _/_/_/
   _/        _/    _/    _/    _/        _/        _/    _/
  _/_/_/    _/_/_/_/    _/    _/        _/_/_/    _/    _/
 _/        _/    _/    _/    _/        _/        _/    _/
_/        _/    _/  _/_/_/  _/_/_/_/  _/_/_/_/  _/_/_/

with 3 errors.

Tx ADDR: 0x02000004: DATA --> HEX: 0x6BAA9455 --> BIN: 0110 1011 1010 1010 1001 0100 0101 0101
Rx ADDR: 0x02000004: DATA --> HEX: 0x00000000 --> BIN: 0000 0000 0000 0000 0000 0000 0000 0000

Tx ADDR: 0x02000008: DATA --> HEX: 0x82E2E662 --> BIN: 1000 0010 1110 0010 1110 0110 0110 0010
Rx ADDR: 0x02000008: DATA --> HEX: 0x00000000 --> BIN: 0000 0000 0000 0000 0000 0000 0000 0000

Tx ADDR: 0x0200000C: DATA --> HEX: 0x7A024204 --> BIN: 0111 1010 0000 0010 0100 0010 0000 0100
Rx ADDR: 0x0200000C: DATA --> HEX: 0x00000000 --> BIN: 0000 0000 0000 0000 0000 0000 0000 0000


DBG02_RAM: 0x82000000 size =    16 bytes, test

    _/_/_/_/    _/_/    _/_/_/  _/        _/_/_/_/  _/_/_/
   _/        _/    _/    _/    _/        _/        _/    _/
  _/_/_/    _/_/_/_/    _/    _/        _/_/_/    _/    _/
 _/        _/    _/    _/    _/        _/        _/    _/
_/        _/    _/  _/_/_/  _/_/_/_/  _/_/_/_/  _/_/_/

with 3 errors.

RAMs TEST STOP ==================================================
```

If the test is successful, the following is displayed:



```
    _/_/_/    _/_/    _/      _/  _/_/_/  _/_/_/_/_/  _/      _/      _/_/_/_/_/  _/_/_/_/    _/_/_/  _/_/_/_/_/
 _/        _/    _/  _/_/    _/    _/        _/        _/  _/            _/      _/        _/            _/
  _/_/    _/_/_/_/  _/  _/  _/    _/        _/          _/              _/      _/_/_/      _/_/        _/
     _/  _/    _/  _/    _/_/    _/        _/          _/              _/      _/              _/      _/
_/_/_/    _/    _/  _/      _/  _/_/_/      _/          _/              _/      _/_/_/_/  _/_/_/        _/


RAMs TEST START ================================================

DBG01_RAM DBG01_RAM: 0x81000000 size =  8192 bytes, test

    _/_/_/      _/_/      _/_/_/    _/_/_/  _/_/_/_/  _/_/_/
   _/    _/  _/    _/  _/        _/        _/        _/    _/
  _/_/_/    _/_/_/_/    _/_/      _/_/    _/_/_/    _/    _/
 _/        _/    _/        _/        _/  _/        _/    _/
_/        _/    _/  _/_/_/    _/_/_/    _/_/_/_/  _/_/_/

DBG02_RAM DBG02_RAM: 0x82000000 size =  8192 bytes, test

    _/_/_/      _/_/      _/_/_/    _/_/_/  _/_/_/_/  _/_/_/
   _/    _/  _/    _/  _/        _/        _/        _/    _/
  _/_/_/    _/_/_/_/    _/_/      _/_/    _/_/_/    _/    _/
 _/        _/    _/        _/        _/  _/        _/    _/
_/        _/    _/  _/_/_/    _/_/_/    _/_/_/_/  _/_/_/

RAMs TEST STOP =================================================
```