VectorBlox™ Video Kit Demo Guide V1.4.4

Purpose

This demo is for CoreVectorBlox neural network acceleration on the PolarFire® field-programmable gate array (FPGA) devices. This document provides instructions on how to use the corresponding reference design.

Intended Audience

This demo guide is intended for:

- FPGA designers
- Firmware designers
- System level designers
- Data scientists

References

The following documents are referred in this demo guide.

- *CoreVectorBlox SDK Programmer's Guide*
- *CoreVectorBlox IP Handbook*

Table of Contents

1. Introduction

This document describes how to run the CoreVectorBlox Neural Network using the PolarFire Video Kit, the Dual Camera sensor module, an HDMI monitor, and optionally a HDMI source such as a laptop. The demo design features a fully integrated solution developed using Microchip Libero® SoC software to help customers evaluate PolarFire FPGA in Neural Network Vision applications and to build prototypes quickly. For more information, see Smart Embedded Vision.

The demo demonstrates the following functions:

- MIPI CSI-2 RX to read one of the cameras
- HDMI display controller
- VectorBlox CNN acceleration of Tiny YOLOv5 (with RELU activations)
- VectorBlox CNN acceleration of Tiny YOLOv4
- VectorBlox CNN acceleration of an image classifier solution featuring MobileNet V2
- Vectorblox CNN acceleration of a face recognition solution featuring SCRFD, Arcface, and GenderAge
- VectorBlox CNN acceleration of license plate detection and recognition
- Image enhancements such as contrast, brightness, and color balance
- Mixed poll and interrupt based approach for demos (polling is used for the recognition demos, and interrupt for simple detection demos)

The PolarFire Video Kit (MPF300-VIDEO-KIT-NS) includes the following components:

- A 300K LE FPGA (MPF300T, FCG1152)
- HDMI 1.4 transmitter (ADV7511) chipset and corresponding connector
- HDMI 2.0 with rail clamps, ReDrivers, and corresponding connectors
- Dual camera sensor featuring IMX334 Sony image sensor
- Image sensor interface to support up to two MIPI CSI-2 cameras
- Display Serial Interface (DSI)
- NVIDIA® Jetson interface (MIPI CSI-2 TX connector)
- A High Pin Count (HPC) FMC connector to connect to high-speed interfaces (such as 12G-SDI and USXGMII)

For more information about the video kit, see PolarFire FPGA Video and Imaging Kit.

1.1 Known Issue

There is a known Reset bug where sometimes the frame buffer management comes out of Reset incorrectly. If the output video is out of sync, try power cycling the board.

2. Design Requirements

The following table lists the hardware and software required to run the demo.

Design Requirements	Description
Hardware Requirements	
PolarFire® Video Kit Development Board	MPF300-VIDEO-KIT-NS
USB A to mini-B cable[(1)]	Required for the following: • FPGA programming and SPI Flash programming • Running the modified Mi-V C code from SoftConsole
HDMI cable[(1)]	HDMI A Male to Male cable
Power adapter[(1)]	12V, 5A
HDMI monitor	A 1920 x1080 60 Hz resolution monitor for the HDMI 1.4 TX port
Host PC	A host PC with a USB port and HDMI output
Software Requirements	
Libero® System-on-Chip (SoC) v2023.1	You must install the full Libero SoC software and not just the programming tools to program the SPI Flash, which cannot be done from FPExpress. A Libero license is necessary; the video kit comes with a Gold license or an evaluation license that can be obtained from the **Licensing** tab of the following page. Libero SoC v12.0 and later
CoreVectorblox License	To configure and synthesize the CoreVectorblox IP, a license is required. It is available at SoC portal. Follow these steps to obtain the license: 1. Click on the **Request Free License** option available on the top right corner. 2. Click on the **Register** button for the required free license option. 3. Enter the Disk ID or MAC ID based on the selected license option and click on the **Register** button. 4. You will receive the license through email. You can also download the license from the MicrochipDirect site.
SoftConsole 2021.1	SoftConsole is required to modify the application Mi-V C code. It is available at: www.microchip.com/en-us/products/fpgas-and-plds/fpga-and-soc-design-tools/soc-fpga/softconsole#Download%20Software

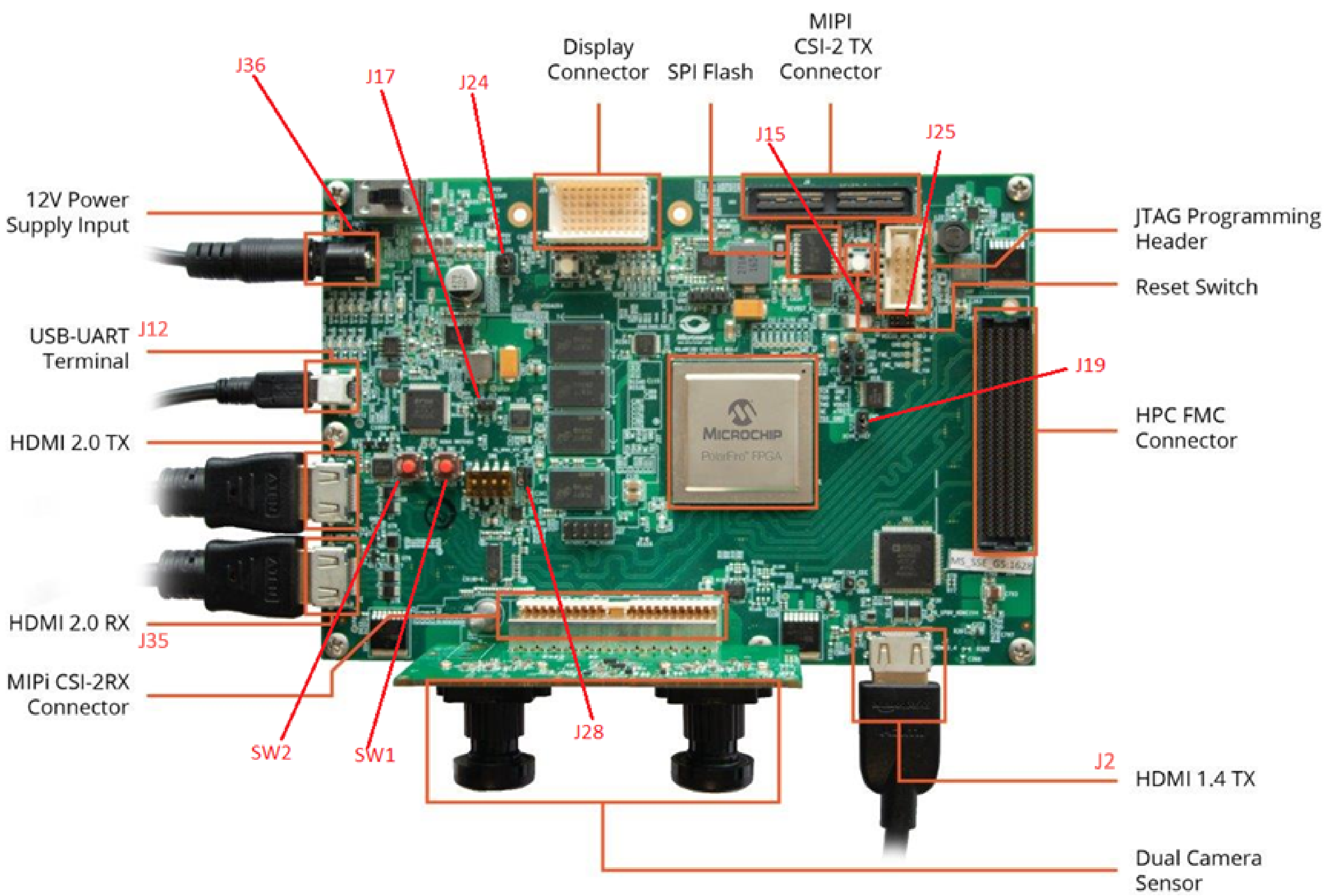
Note:

1. Included with the PolarFire Video Kit.

3. Development Kit for Demo

The following figure highlights the features of PolarFire Video Kit.

Figure 3-1. PolarFire Video Kit Features



The following table provides the jumper position and functionality for the jumper settings.

Table 3-1. Jumper Description

Jumper/Switch	Default Position	Functionality
J15	Open	SPI Slave and Master mode selection. Default: SPI master.
J17	Open	100K PD for TRSTn. Default: 1K PD is connected.
J19	Pin1 and 2	Default: XCVR_VREF is connected to GND.
J28	Pin 1 and 2	Default: Programming through the FTDI.
J24	Pin 2 and 4	Default: VDDAUX4 voltage is set to 3V3.
J25	Pin 5 and 6	Default: Bank4 voltage is set to 1V8.
J36	Pin 1 and 2	Default: Board power-up through SW4.

...........continued

Jumper/Switch	Default Position	Functionality
SW1	—	Opens model selection menu, and loads highlighted model from menu.
SW2	—	Cycles through model selection menu if open. When the face demo is running and the model menu is not open, pressing this button toggles the GenderAge network on/off.

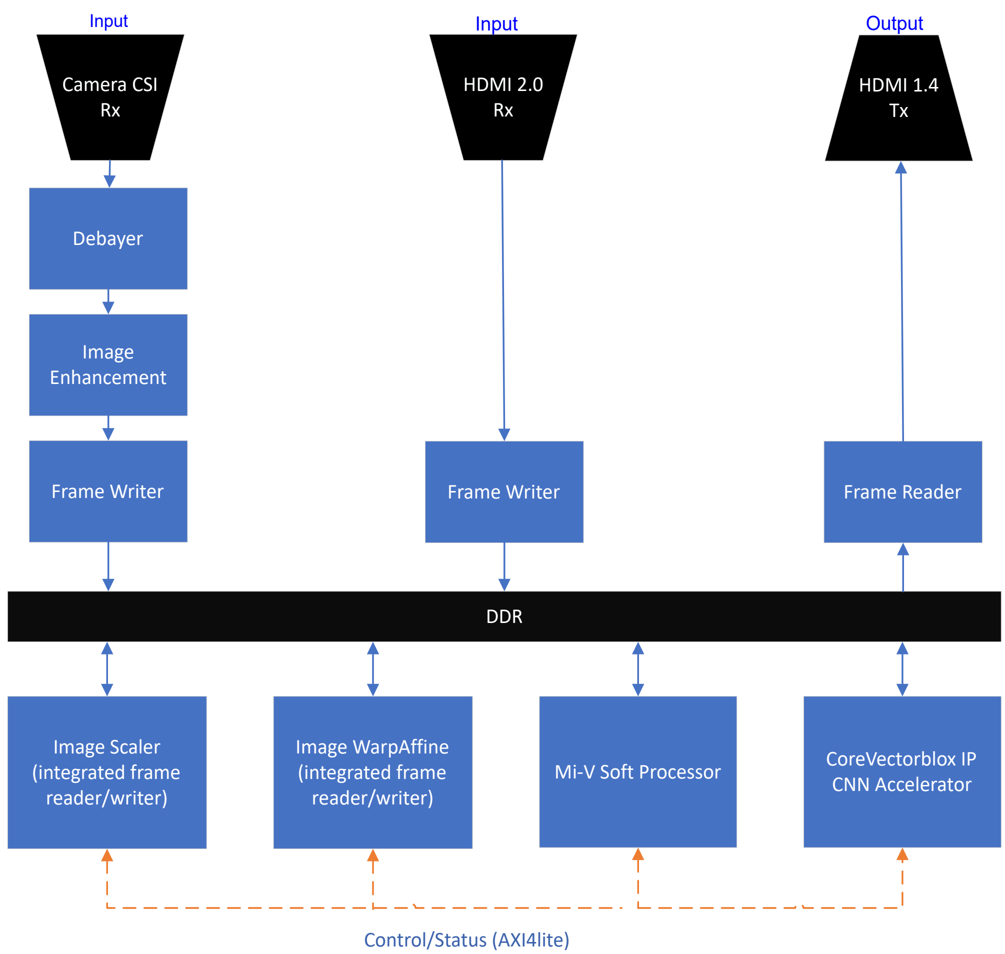
4. Demo Design Description

The following section provides an overview of the dataflow in the demo design. This system design allows the mobilnet, yolo, license plate, and the face recognition demo to run on the same hardware.

4.1 System Design

The following diagram illustrates an overview of the dataflow in the design.

Figure 4-1. System Dataflow



Sequence of data flow shown in the figure above is as follows:

1. Input
   a. Received from MIPI CSI 2: Video frame data is passed through a debayer and Image Enhancement block to a Frame Writer which writes the video data to DDR.
   b. Received from HDMI Rx: If a source is connected to J35, the video frame data is sent directly to a Frame Writer which writes the video data to DDR.
2. Based on demo requirements, Mi-V instructs the Image Scaler and/or the Image WarpAffine block to process the input frame appropriately for CNN(s). If an HDMI source is present, the input frame is taken from HDMI, otherwise it is taken from the camera. The result of scaling and warping is written to DDR.
3. Mi-V instructs CoreVectorBlox IP to run the appropriate CNN using the scaled and warped image as input to CNN. The result of CNN is written back to DDR by CoreVectorBlox IP.
4. Mi-V reads the result of CNN from DDR and runs post-processing software routines. The result is then drawn on the original Input Frame Buffer.
5. The Frame Reader reads the frame and streams the frame data to the HDMI Tx block.

5. Setting Up the Demo

The following steps describe how to setup the demo.

1. Setting up the Hardware
2. Programming the PolarFire Device
3. Programming the SPI Flash

5.1 Setting Up the Hardware

Setting up the hardware involves interfacing the dual camera sensor module and the HDMI monitor with the PolarFire Video Kit, and verifying the jumper settings.

Perform the following steps.

1. Connect the J1 connector of the dual camera sensor module to the J5 interface of the video kit. The video kit is already shipped with this.
2. Connect the Full HD HDMI (1080P) monitor to J2 (HDMI 1.4 TX port) of the video kit using the HDMI cable.
3. Connect the host PC to J12 of the video kit using the USB mini cable.
4. Connect the power supply cable to J20 of the video kit.
5. Ensure that the jumper settings are set on the video kit. The video kit is shipped in this configuration. For jumper position and functionality, see Table 3-1.
6. Power-up the HDMI monitor.
7. Power-up the board using the SW4 slide switch.
8. Optionally, if running the face recognition or license plate recognition demos, connect HDMI source playing `SampleFaces.mp4` or `SamplePlates.mp4` respectively (supplied with the project ZIP file) fullscreen to the HDMI 2.0 RX port (J35).

The PolarFire dual camera video and imaging hardware setup is completed.

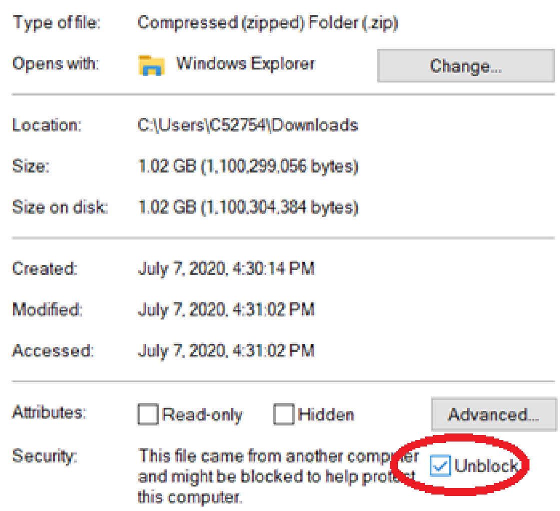
5.2 Programming the PolarFire Video Kit

The following section describes how to program the PolarFire device and run the demo.

5.2.1 Extracting the Source files and Opening the Project

Before unzipping the archive containing the libero project, first “unblock” the file. This is necessary to ensure that Windows does not change the timestamps of the files during extraction. To unblock the file, right click the zip file, select **Properties** and check **Unblock**, then click **OK**.

Figure 5-1. Unblocking the File



After unzipping the archive, launch Libero SoC v2023.1, and navigate to **Project** > **Open Project**. Then, open the `vectorblox_videokit_v1.4.4/vectorblox_videokit_v1.4.4.prjx` project file.

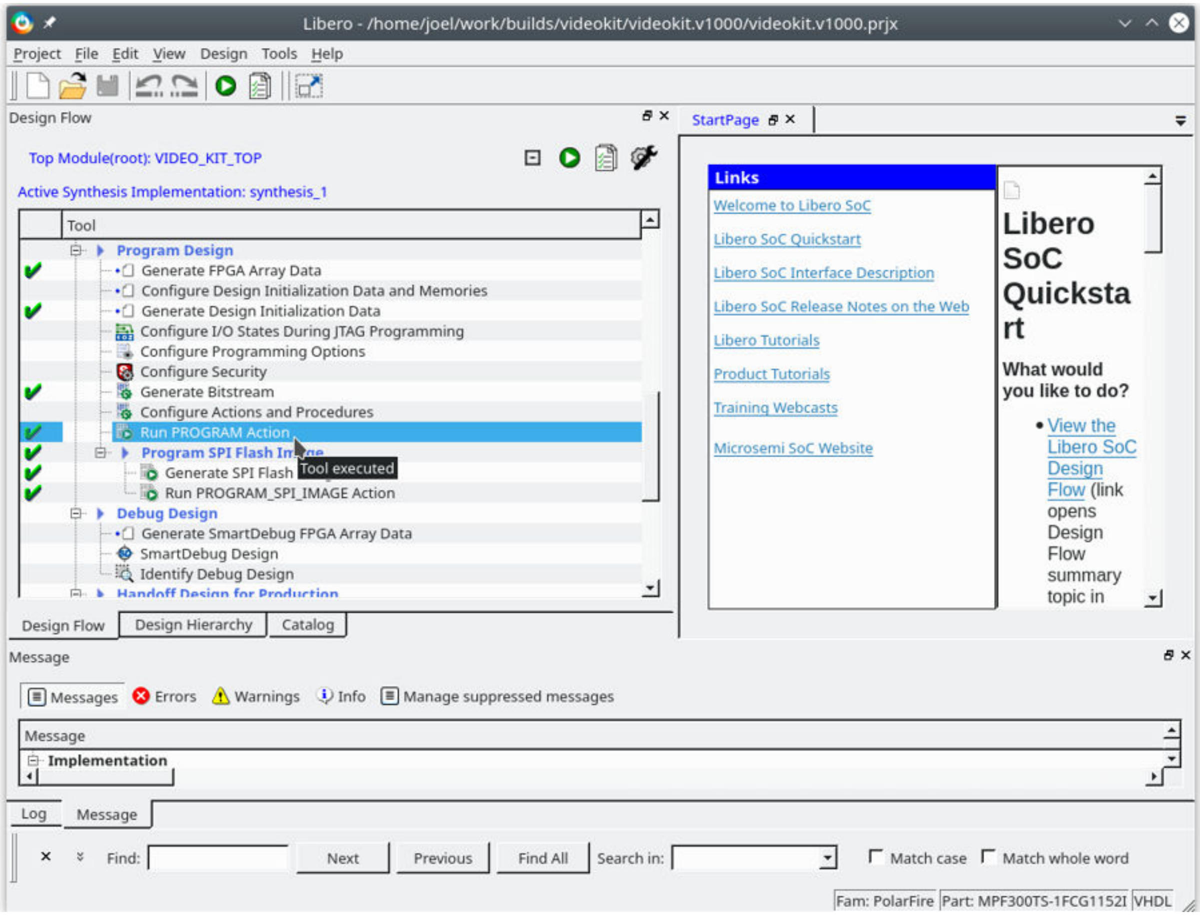
Note: You may be prompted to update Libero SoC or individual IP cores, ignore these prompts.

5.2.2 Programming the Device

Perform the following steps.

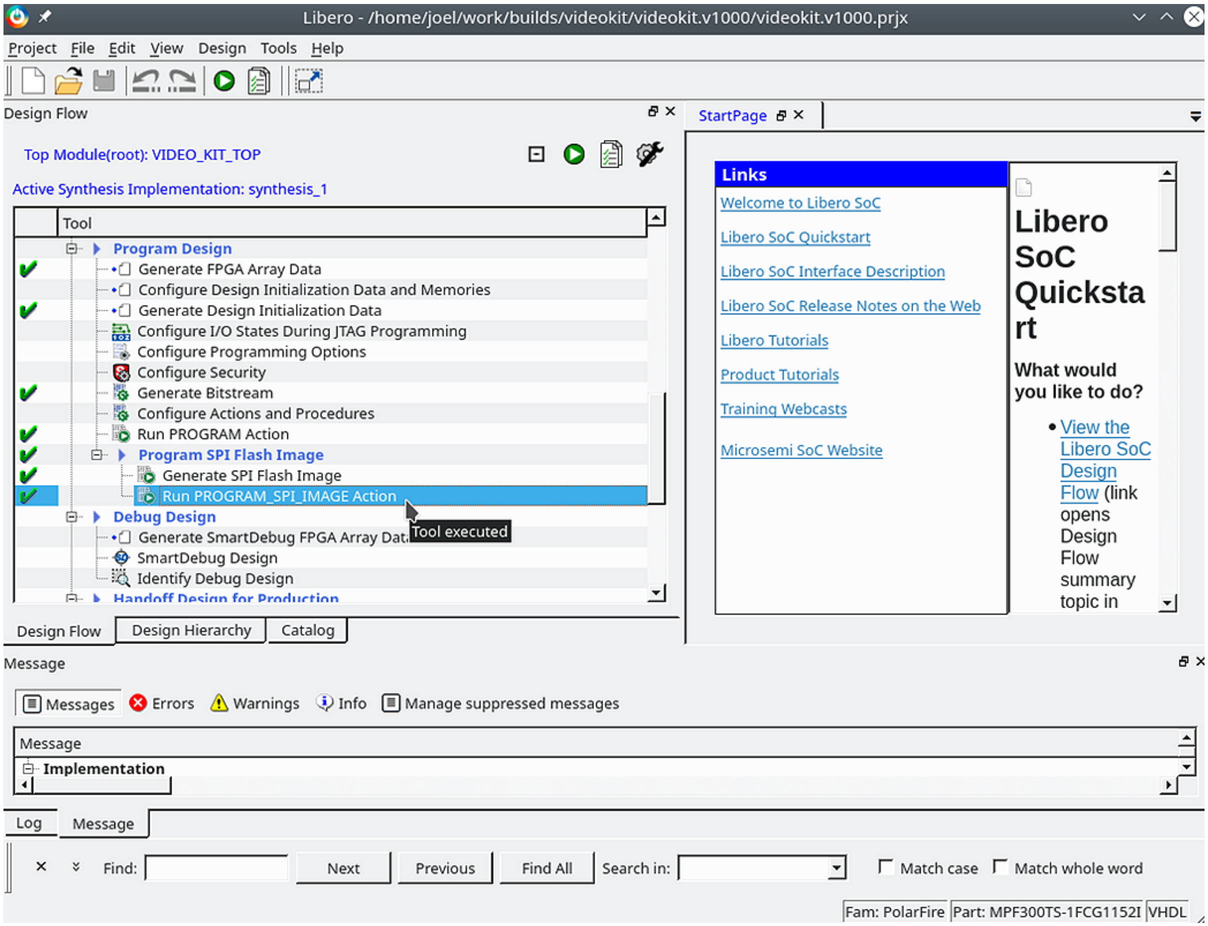
1. In the **Design Flow** window, double click **Run PROGRAM Action**.

Figure 5-2. Run PROGRAM ACTION



2. Double click **Run PROGRAM_SPI_IMAGE Action** and wait. This will take some time.
Notes:
   - In Windows, you might be prompted with a firewall popup.
   - Ignore any warnings about misaligned sectors.

Figure 5-3. Run PROGRAM_SPI_IMAGE Action



5.2.3 Running the Demo

Power cycle the board with SW4 to start the demo.

The startup takes a few minutes. The following events occur during the startup: the camera is calibrated to the brightness of the environment, the firmware and models are read from the Flash into DDR.

After the startup is completed, the face demo using SCRFD and Arcface will be run to find faces.

Note: Sometimes the demo might appear to start correctly without a power cycle but actually be in an Incoherent state.

If faces are found, it runs Arcface for one of the faces to identify the face. If more than one face is found, the other faces will rely on the Kalman filter tracking to keep track of the name of the face. If GenderAge is also running, then the same face that ran with Arcface runs with GenderAge to predict the gender (M/F) and age of the person.

You can select the source of the frames that needs to be processed by the network. The source is determined by connecting to the J35 connector. An HDMI cable connecting a video source (for example, from a laptop) will take priority over the image sensor coming with the video kit. If the HDMI cable is not connected to J35, the image sensor will be selected as the source.

If running the face demo or license plate demo, the `SampleFaces.mp4` or `SamplePlates.mp4` can be played from an HDMI source connected to J35 to demonstrate their recognitions, respectively.

5.2.4 Switching Models from Model Menu

After start-up, the currently running network can be swapped out for another network programmed in the SPI Flash. By default, the demo is programmed with the face demo (loaded on start), a license plate demo, MobileNet V2 demo, a YOLOv5n, and a Tiny YOLOv4 demo. To switch to the other networks, perform the following:

1. Press the SW1 button switch to open the model menu.
2. Use the SW2 button switch to cycle downward through the model menu.
3. Press the SW1 button switch again when highlighting the model you wish to load.

After the network is loaded from the SPI Flash first time, it is not re-loaded again from the SPI Flash until the board is powercycled.

Note: When the face demo is running and the model menu is not open, press the SW2 button to toggle on/off the GenderAge network.

6. Running Alternate Models

By default, the demo runs the face demo on start-up, and can switch to run MobileNet V2, license plate demo, YOLOv5n, and YOLOv4. However, it is capable of running many other networks. In this document, you will see an example of adding in a new network, Tiny YOLOv3.
Note: If adding a new model, simple detection models will use an interrupt based approach, while recognition focused demos will use a poll based approach.

Currently, post-processing routines exist for TinyYoloV2 (VOC), TinyYoloV3 (COCO), TinyYoloV4 (COCO), YoloV5 (COCO), SCRFD, license plate detection, license plate recognition, Retinaface, Blazeface, Sphereface/Arcface (face recognition), and Imagenet networks. Users will have to write additional post-processing code to run other networks.

The following sections describe how to run the alternate models.

6.1 Obtaining Model File

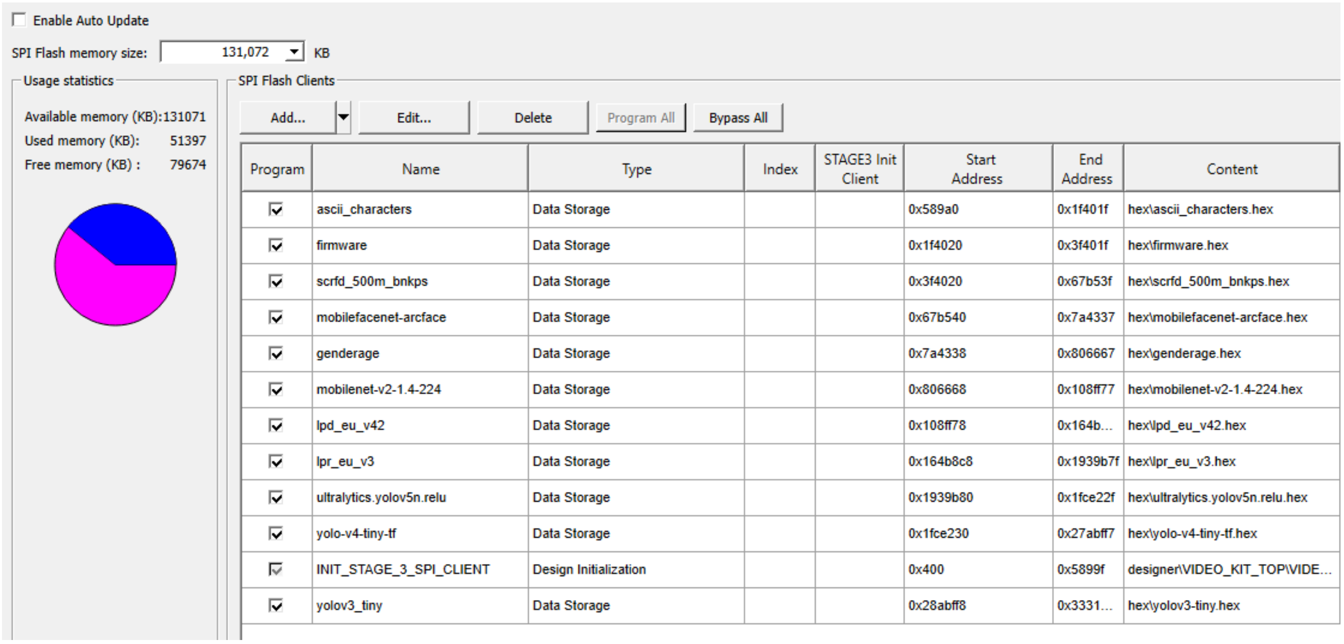
The model files can be obtained by running the tutorial available in the VectorBlox SDK in github.com/Microchip-Vectorblox/VectorBlox-SDK/tree/release-v1.4.4. Instructions for running the tutorials can be found in the Programmer's Guide available as part of the SDK documentation. Generate the model using this tutorial: `VectorBlox-SDK-release-v1.4.4/tutorials/darknet/yolov3-tiny`. The artifact generated from the tutorial that needs to be stored is `yolov3-tiny.hex`. This hex file is added to the SPI Flash on the board.

6.2 Modifying the SPI Flash Configuration

Perform the following steps in Libero.

1. Invoke the “Configure Design Initialization Data and Memories” tool in the Libero Design Flow.
2. To view all the SPI Flash clients, click on the **SPI Flash** tab at the top of the “Configure Design Initialization Data and Memories” tool.
3. To add a new model, click the **Add** button, and select the **Add Data Storage Client** option. Change the path to point to `yolov3-tiny.hex` (file described in the preceeding section, Obtaining Model File).
   Note: Ensure the address range does not overlap with other clients in the Flash memory.
4. Click **Apply**.
5. In the **Design Flow** window, double click **Run PROGRAM_SPI_FLASH Action** (see Step 2 in the Programming the Device section).
6. Click **Yes** to ignore warnings about memory alignment.
7. After the SPI programming is complete, power cycle the board using SW4.

Figure 6-1. SPI Configuration after Modification



6.3 SoftConsole Project

Before the new model is run on the FPGA, the software running on Mi-V must be modified as described in this section.

A SoftConsole project is located in the Libero Design zip archive at `Download_Directory/vectorblox_videokit_v1.4.4/softconsole`. In either SoftConsole 2022 (or 2021), open the project in your workspace.

Figure 6-2. Open Projects in SoftConsole

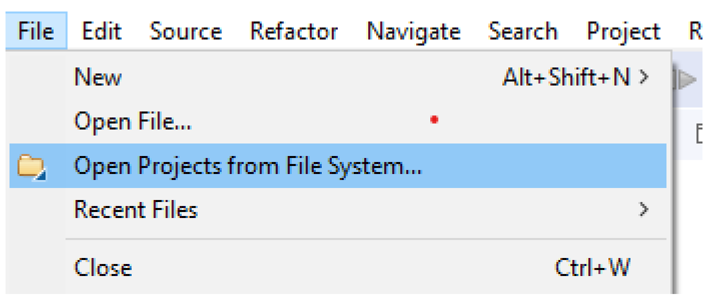
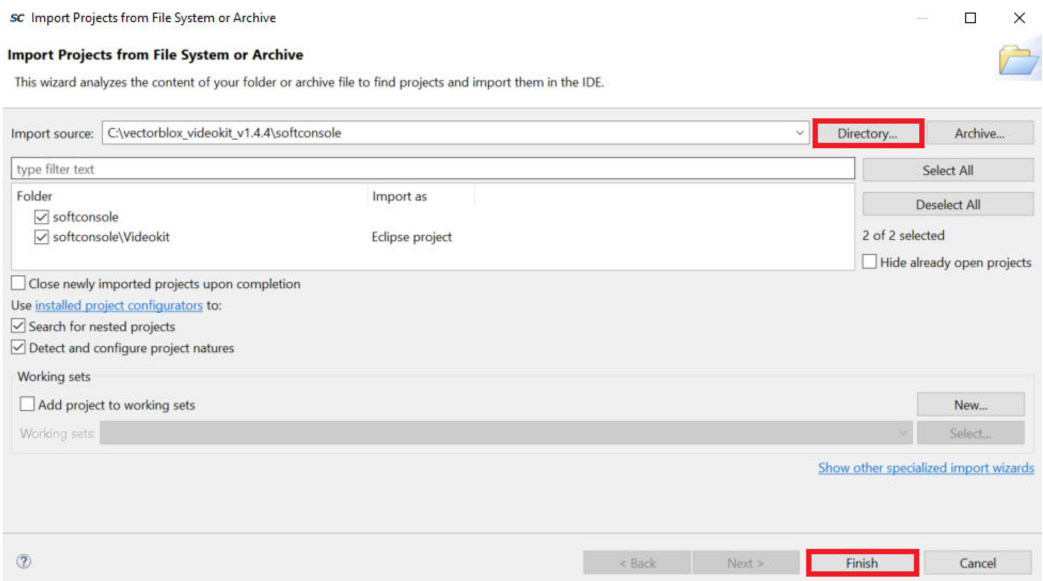


Figure 6-3. Import Projects from File System or Archive



In the VideoKit project locate and open `main.c`. The following code can be seen on line 47.

```
struct model_descr_t models[] = {
                                {"SCRFD","",0x3f4020, "SCRFD"},
                                {"ArcFace","",0x67b540, "ARCFACE"},
                                {"GenderAge","",0x7a4338, "GENDERAGE"},
                                {"LPD","",0x108ff78, "LPD"},
                                {"LPR","",0x164b8c8, "LPR"},
                                {"MobileNet V2","",0x806668, "IMAGENET"},
                                {"Yolo V5 Nano","",0x1939b80, "YOLOV5"},
                                {"Tiny Yolo V4 COCO","",0x1fce230, "YOLOV4"},
};
```

Change the code to the following.

```
struct model_descr_t models[] = {
                                {"SCRFD","",0x3f4020, "SCRFD"},
                                {"ArcFace","",0x67b540, "ARCFACE"},
                                {"GenderAge","",0x7a4338, "GENDERAGE"},
                                {"LPD","",0x108ff78, "LPD"},
                                {"LPR","",0x164b8c8, "LPR"},
                                {"MobileNet V2","",0x806668, "IMAGENET"},
                                {"Yolo V5 Nano","",0x1939b80, "YOLOV5"},
                                {"Tiny Yolo V4 COCO","",0x1fce230, "YOLOV4"},
                                {"Tiny Yolo V3 COCO","",0x28abff8, "YOLOV3"},
};
```

Where, parameters in the structure are as follows:

- Display name of the model
- Address in the SPI Memory in which the model is stored.
- The type of postprocessing for displaying the network. See 6. Running Alternate Models for the supported postprocessing implementations.

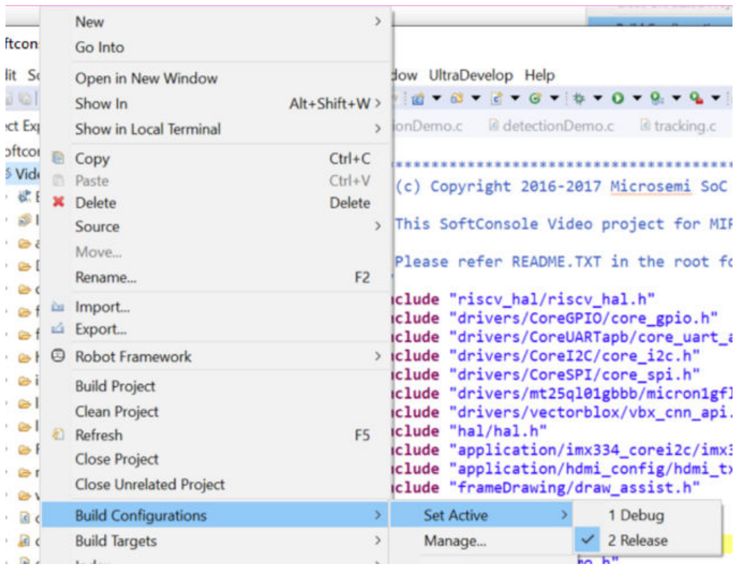
After these modifications are performed, save the `main.c` file, and build the project. The software is now ready to run and models can be executed.

Ensure that the Build Configurations are set to Release Mode. This can be done by right clicking the VideoKit.

Notes:

- Face detection and face recognition are expected to be added in pairs, with the face detection network listed first, followed immediately by the face recognition model.
- License plate detection and recognition are also expected to be added in pairs. The plate recognition network must immediately follow the plate detection network.

Figure 6-4. Build Configuration



6.4 Running the Mi-V Program

Make sure to use FP5 and jumper J28 connects Pin 1 to Pin 2. To run the Mi-V program, click the  button in the toolbar.

6.5 Flashing New Software

Alternatively, to avoid having to manually run the Mi-V program on every start-up if making changes to the project in SoftConsole, the Fabric RAM can be configured to load your changes automatically.

If the build was successful, follow these steps:

1. Verify the timestamp of `softconsole/Videokit/Release/Videokit.hex` is up to date.
2. In Libero, click on **Configure Design Initialization Data and Memories**.
3. Click on **Fabric RAMs** tab.
4. Click edit on the entry that uses `softconsole/Videokit/Release/Videokit.hex`. This entry is named `PROC_SUBSYSTEM_0/PF_SRAM_AHBL_AXI_C1_0`.
5. Select your modified `Videokit.hex` file, click **OK**, then click **Apply** tab.
6. Double click **Run PROGRAM_SPI_IMAGE Action** to update the required steps.

7. Error Debugging

If an error is encountered, both of the relevant error message and error code are written out over the HDMI output display and to UART. Consult the CoreVectorBlox IP Handbook for more information and to proceed with next steps.

8. Revision History

The revision history describes the changes that were implemented in the document. The changes are listed by revision, starting with the most current publication.

Revision	Date	Description
H	08/2023	Updated to 1.4.4 Release
G	04/2023	Updated to 1.4.3 Release
F	09/2022	Updated to 1.4 Release
E	02/2022	Updated to 1.3 Release
D	09/2021	Updated to 1.2 Release
C	05/2021	Updated to 1.1 Release
B	11/2020	Updated to 1.0 Release
A	08/2020	Initial Revision

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