# 1. seL4 Test on the Polarfire SoC

## *1.1. Get the Code*

Use the repo tool to get the code from a manifest and start building:

```
mkdir sel4test
cd sel4test
repo init -u https://github.com/dornerworks/sel4test-manifest -b polarfire -m
master.xml
repo sync
```

These instructions will download the tools and code required to build the seL4 kernel and the seL4 test suite. This directory will be referred to as the workspace.

## *1.2. Build the Code*

The manifest does not, however, install a toolchain to build the code. For this, Data 61 does maintain a Docker image that contains all of the necessary development packages and cross compiling toolchains.

Clone this repository into the `tools` directory of your workspace:

```
git clone https://github.com/SEL4PROJ/seL4-CAmkES-L4v-dockerfiles
tools/DockerFiles
```

I like to create a script in the root of my workspace called `container-env.sh` that has the following contents:

```
#!/bin/bash

DOCKER_PATH="./tools/DockerFiles"
pwddir="$(pwd)"
host_dir="${pwddir// /\\ }"
image_name=$(whoami)-sel4-riscv

# Removing the requirement for a stack group from haskell, we're not using
haskell
if [ $(grep "\-\-group-add stack" tools/DockerFiles/Makefile | wc -l) -ge 0 ];
then
    sed -i "/--group-add stack/d" tools/DockerFiles/Makefile
fi

function doc () {
    echo "seL4 Docker Development Environment"
    echo "-----------------------------------"
    echo "Loaded Functions: "
    echo " [1] start-container"
    echo "       Doc: Drop to an interactive shell in the containerized
development environment"
    echo "        Ex:    Interactive shell: start-container"
    echo " [2] container-command [\"command\"]"
    echo "       Doc: Run the command in quotes inside of the container and
exit"
    echo "       Ex:   Run a command: container-command \"/host/run-build.sh -p
polarfire\""
}

function start-container() {
```

```
    make -C ${DOCKER_PATH} user_sel4-riscv \
         USER_IMG=${image_name} \
         HOST_DIR=$(pwd)
}

function container-command () {
    if [[ $# == 0 ]]; then
        echo "Error: Must provide a command"
        doc
    else
        make -C ${DOCKER_PATH} user_sel4-riscv \
             USER_IMG=${image_name} \
             HOST_DIR=$(pwd) \
             EXEC="bash -c '""$@""'"
    fi
}

if [ -d ${DOCKER_PATH} ]; then
    doc
else
    echo "Your containerized environment does not seem to be installed at
${DOCKER_PATH}"
    echo "Please install it there"
fi
```

I like to open two terminals at this point. In this situation, I can have my container environment in one terminal and my development tools on my host machine accessible in the other. In the terminal that the `container-env.sh` file was sourced, run the `start-container` command. You should be dropped into a shell prompt, where you should also see the directory structure of your workspace.

Here, we will create a build directory and call the `init-build.sh` script to configure and kick off the build:

```
mkdir build-polarfire
cd build-polarfire
../init-build.sh \
  -DPLATFORM=polarfire \
  -DSIMULATION=FALSE \
  -DElfloaderImage=binary \
  -DSel4testAllowSettingsOverride=True \
  -DLibSel4PlatSupportUseDebugPutChar=OFF \
  -DCMAKE_BUILD_TYPE=Debug \
  -DKernelDebugBuild=ON \
  -DRELEASE=False \
  -DUseRiscVBBL=false \
  -DKernelVerificationBuild=OFF \
  -DKernelPrinting=ON \
  -DRISCV64=TRUE \
  -DSel4testHaveTimer=OFF
ninja
```

The image will now be located in `<Workspace Root>/build-polarfire/images/sel4test-driver-image-riscv-polarfire`. The image that is created is actually the `elfloader`, `kernel`, and user space sel4test application all rolled into one. This is not a bootable image just yet though.

### *1.3. Run the code on the Renode PolarFire SoC model*

As a disclaimer, the whole test suite does not run right now on the Renode model. However, AntMicro has recently brought seL4 test into their own CI infrastructure so this will hopefully help make their implementation better.

To run on the Renode emulator, we have to build a slightly different version of our image. The bootloader used on the board is a little more advanced and not yet directly supported by the seL4 build system. However, the Berkeley Bootloader (BBL) is. Create a new build directory and run the same `init-build.sh` command as before but this time we will use slightly different options:

```
../init-build.sh \
  -DPLATFORM=polarfire \
  -DSIMULATION=FALSE \
  -DElfloaderImage=elf \
  -DSel4testAllowSettingsOverride=True \
  -DLibSel4PlatSupportUseDebugPutChar=OFF \
  -DCMAKE_BUILD_TYPE=Debug \
  -DKernelDebugBuild=ON \
  -DRELEASE=False \
  -DUseRiscVBBL=false \
  -DKernelVerificationBuild=OFF \
  -DKernelPrinting=ON \
  -DRISCV64=TRUE \
  -DSel4testHaveTimer=OFF \
  -DUseRiscVBBL=True
ninja
```

Here, we changed the `ElfloaderImage` option from `binary` to `elf` and added the `-DUseRiscVBBL=True` to the options. This will bundle everything we had before into a payload for the BBL. We are now ready to use Renode.

Create a file called `sel4test-polarfire.resc` in the root of your workspace and fill it with the following contents:

```
:name seL4 Test
:description Runs seL4 Test on Renode

$name?="sel4test"

using sysbus
mach create $name
$bin?=@./build-polarfire/images/sel4test-driver-image-riscv-polarfire
$dtb?=@./build-polarfire/kernel/kernel.dtb
machine LoadPlatformDescription @platforms/boards/mpfs-icicle-kit.repl

showAnalyzer mmuart0
showAnalyzer mmuart3

macro reset
"""
  sysbus LoadELF $bin
  sysbus LoadFdt $dtb 0x81000000 "earlyconsole mem=256M@0x80000000"
  e51 SetRegisterUnsafe 11 0x81000000
  u54_1 SetRegisterUnsafe 11 0x81000000
"""
runMacro $reset
```

Make sure that the `bin` and `dtb` variables point to the actual files. You can now run `renode`

`sel4test-polarfire.resc`.

You should now see the Renode monitor window come up. Type `start` here and press Enter. You will see more terminal windows pop up. You should see the kernel printing in one and the user space code in the other.

### *1.4. Run the code on the PolarFire SoC Hardware*

First we must make a bootable SD card image. This requires using Yocto. Yocto is out of the scope of this tutorial but follow the directions located at the PolarFire SoC Yocto BSP site. Build the SD card image and follow the instructions for using `dd` to write the `wic.gz` image to the SD Card. Copy your `sel4test` image that you build to the `boot` partition as `sel4test`.

Ensure that the PolarFire SoC board is configured to boot from an SD Card and insert the SD card. At this point I like to use tmux to split a terminal into 4 parts and then use `tio` to connect each pane to a serial device. I run the following command to achieve this:

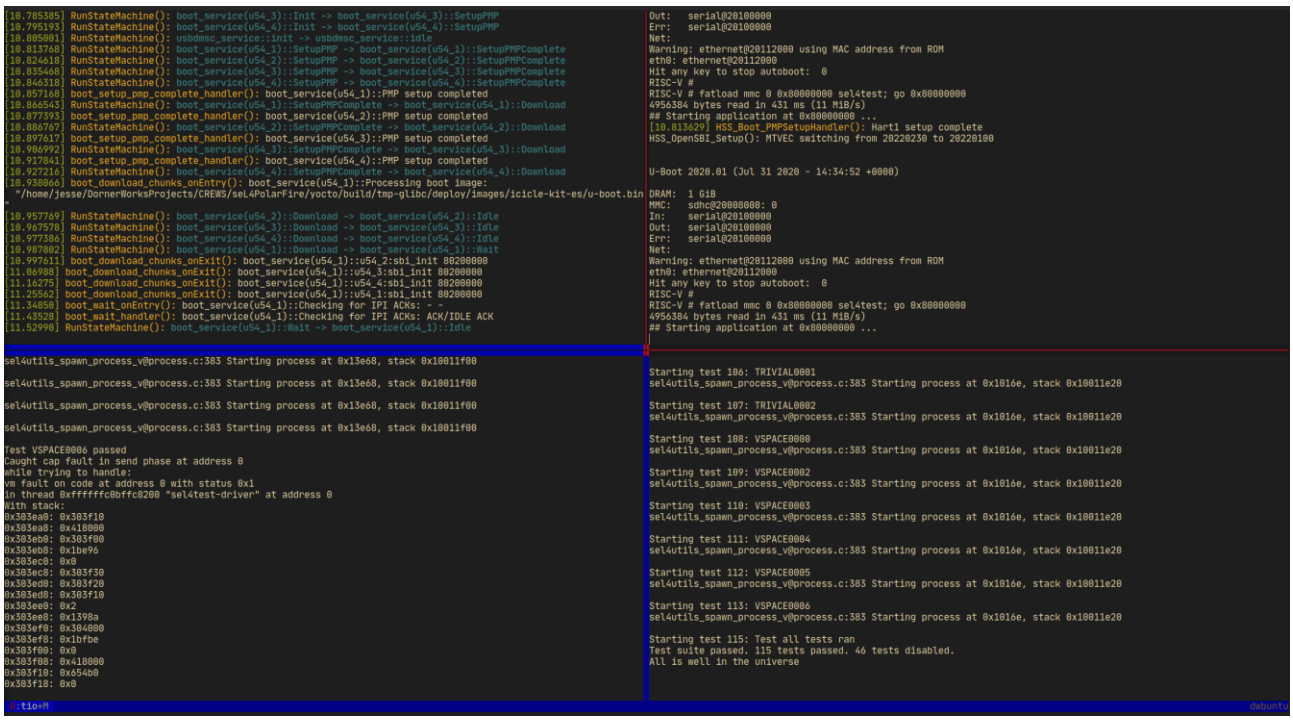
```
tmux new-session -d -s 'polarfire-serial-dashboard'
tmux split-window -v
tmux split-window -h
tmux select-pane -t 0
tmux split-window -h
tmux respawn-pane -t0 -k "tio /dev/ttyUSB0"
tmux respawn-pane -t1 -k "tio /dev/ttyUSB1"
tmux respawn-pane -t2 -k "tio /dev/ttyUSB2"
tmux respawn-pane -t3 -k "tio /dev/ttyUSB3"
tmux select-layout tiled
tmux set -g mouse on
tmux attach-session -t 'polarfire-serial-dashboard'
```

When you power on the board, you should see the Hart Software Services boot up in the upper left terminal. This is the software running on the monitor core. The upper right terminal will show the output from U-Boot. Make sure that you are ready with tmux to select this pane. The lower left pane will show the output from the kernel, while the last pane will show the output from the user space seL4 test application suite. When the board powers on be sure to interrupt the U-boot sequence and enter the following `fatload` command:

```
U-Boot 2020.01 (Jul 31 2020 - 14:34:52 +0000)

DRAM:  1 GiB
MMC:   sdhc@20008000: 0
In:    serial@20100000
Out:   serial@20100000
Err:   serial@20100000
Net:
Warning: ethernet@20112000 using MAC address from ROM
eth0: ethernet@20112000
Hit any key to stop autoboot:  0
RISC-V #
RISC-V # fatload mmc 0 0x80000000 sel4test; go 0x80000000
```

You should see debug statements printing on the kernel terminal and test output in the lower right.




A success full test run shows "All is well in the universe" at the end.

## 2. Where to go from here

We have a few rough edges to sand down here. First, we are working on adding functionality to the build system to make building a bootable image without yocto easy from the current build system. Second, We are working on a timer driver for the PolarFire SoC. Lastly, the platform support for the PolarFire SoC is under review by Data 61 for inclusion upstream. When the patches are accepted upstream, the only difference to these instructions will be the original `sel4test-manifest` link that was used.