

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 \  
-DElfloderImage=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 `ElfloderImage` 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.

```

10.795395 RunStateMachine(): boot_service(u54_3)::Init -> boot_service(u54_3)::SetupPPP
10.795193 RunStateMachine(): boot_service(u54_4)::Init -> boot_service(u54_4)::SetupPPP
10.805901 RunStateMachine(): usbdmcc_service::init -> usbdmcc_service::idle
10.813768 RunStateMachine(): boot_service(u54_1)::SetupPPP -> boot_service(u54_1)::SetupPPPComplete
10.824618 RunStateMachine(): boot_service(u54_2)::SetupPPP -> boot_service(u54_2)::SetupPPPComplete
10.835468 RunStateMachine(): boot_service(u54_3)::SetupPPP -> boot_service(u54_3)::SetupPPPComplete
10.846318 RunStateMachine(): boot_service(u54_4)::SetupPPP -> boot_service(u54_4)::SetupPPPComplete
10.857168 boot_setup_ppm_complete_handler(): boot_service(u54_1)::PPP setup completed
10.866543 RunStateMachine(): boot_service(u54_1)::SetupPPPComplete -> boot_service(u54_1)::Download
10.877393 boot_setup_ppm_complete_handler(): boot_service(u54_2)::PPP setup completed
10.888767 RunStateMachine(): boot_service(u54_2)::SetupPPPComplete -> boot_service(u54_2)::Download
10.897617 boot_setup_ppm_complete_handler(): boot_service(u54_3)::PPP setup completed
10.908992 RunStateMachine(): boot_service(u54_3)::SetupPPPComplete -> boot_service(u54_3)::Download
10.917841 boot_setup_ppm_complete_handler(): boot_service(u54_4)::PPP setup completed
10.927216 RunStateMachine(): boot_service(u54_4)::SetupPPPComplete -> boot_service(u54_4)::Download
10.938066 boot_download_chunks_onEntry(): boot_service(u54_1)::Processing boot image:
"/home/jesse/BorderworksProjects/CREMS/seL4PolarFire/yocto/build/tmp-glibc/dep/yocto/images/icicle-kit-ef-u-boot.bin"
10.957769 RunStateMachine(): boot_service(u54_2)::Download -> boot_service(u54_2)::Idle
10.967578 RunStateMachine(): boot_service(u54_3)::Download -> boot_service(u54_3)::Idle
10.977386 RunStateMachine(): boot_service(u54_4)::Download -> boot_service(u54_4)::Idle
10.987802 RunStateMachine(): boot_service(u54_1)::Download -> boot_service(u54_1)::Wait
10.997611 boot_download_chunks_onExit(): boot_service(u54_1)::u54_2:sbi_init 80200000
11.009803 boot_download_chunks_onExit(): boot_service(u54_1)::u54_3:sbi_init 80200000
11.16275 boot_download_chunks_onExit(): boot_service(u54_1)::u54_4:sbi_init 80200000
11.25562 boot_download_chunks_onExit(): boot_service(u54_1)::u54_1:sbi_init 80200000
11.34850 boot_wait_onEntry(): boot_service(u54_1)::Checking for IPI ACKs: -
11.43520 boot_wait_handler(): boot_service(u54_1)::Checking for IPI ACKs: ACK/IDLE ACK
11.52990 RunStateMachine(): boot_service(u54_1)::Wait -> boot_service(u54_1)::Idle

Out: serial@20180800
Err: serial@20180800
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
4956384 bytes read in 431 ms (11 MiB/s)
## Starting application at 0x80000000 ...
(10.10307) HSS_boot_ppmSetupHandler(): HwT1 setup complete
HSS_OpenSBI_Setup(): MTEC switching from 20220230 to 20220100

U-Boot 2020.01 (Jul 31 2020 - 14:34:52 +0800)

DRAM: 1 GiB
MMC: sdhc@20000000: 0
In: serial@20180800
Out: serial@20180800
Err: serial@20180800
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
4956384 bytes read in 431 ms (11 MiB/s)
## Starting application at 0x80000000 ...

sel4utils_spawn_process_v@process.c:383 Starting process at 0x13e68, stack 0x10011f00

test VSPACE0006 passed
caught cap fault in send phase at address 0
while trying to handle:
vm fault on code at address 0 with status 0x1
in thread 0xfffffc0bffc520 "sel4test-driver" at address 0
with stack:
0x303e90: 0x303f10
0x303e94: 0x18000
0x303e98: 0x303f00
0x303ea0: 0x1be96
0x303ea4: 0x0
0x303ea8: 0x303f30
0x303eac: 0x303f20
0x303eb0: 0x303f10
0x303eb4: 0x4
0x303e80: 0x1398a
0x303ef0: 0x104000
0x303ef4: 0x11f9e
0x303f00: 0x0
0x303f08: 0x418000
0x303f10: 0x45400
0x303f18: 0x0

Starting test 106: TRIVIAL0001
sel4utils_spawn_process_v@process.c:383 Starting process at 0x1016e, stack 0x10011e20
Starting test 107: TRIVIAL0002
sel4utils_spawn_process_v@process.c:383 Starting process at 0x1016e, stack 0x10011e20
Starting test 108: VSPACE0000
sel4utils_spawn_process_v@process.c:383 Starting process at 0x1016e, stack 0x10011e20
Starting test 109: VSPACE0002
sel4utils_spawn_process_v@process.c:383 Starting process at 0x1016e, stack 0x10011e20
Starting test 110: VSPACE0003
sel4utils_spawn_process_v@process.c:383 Starting process at 0x1016e, stack 0x10011e20
Starting test 111: VSPACE0004
sel4utils_spawn_process_v@process.c:383 Starting process at 0x1016e, stack 0x10011e20
Starting test 112: VSPACE0005
sel4utils_spawn_process_v@process.c:383 Starting process at 0x1016e, stack 0x10011e20
Starting test 113: VSPACE0006
sel4utils_spawn_process_v@process.c:383 Starting process at 0x1016e, stack 0x10011e20
Starting test 115: Test all tests ran
Test suite passed. 115 tests passed. 46 tests disabled.
All is well in the universe

```

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.