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REFERENCE SOFTWARE FOR XRS AND FRS REFERENCE DESIGNS

User Guide

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Revision History

Rev	Date	Comments
1.0	12.2.2016	First version
1.1	29.6.2016	Raspberry Pi 3 Model B support XRS register access method selection
1.2	31.5.2021	Added FRS designs to scope of this document. Add Raspberry Pi Model 4 B 4GB support Drop Raspberry Pi model 1 B support Drop references to Raspbian Replace Apache HTTP server by Nginx HTTP server Drop flx_i2c_gpio driver (mainline i2c-gpio is used) Drop dp8384 driver (mainline dp83848 is used) Revise Raspberry Pi boot description

1 About This Document

This document is a reference software user guide for XRS7004E and XRS7003E devices [1] and FRS SoC evaluation card. The main idea of the reference software is to provide a software environment for Flexibilis product evaluation. The software consists of two parts: First part is a Disk Image, an SD card image for Raspberry Pi which is used with Flexibilis XRS Reference Board [2] or SD card image for FRS SoC evaluation card. Second part is XRS and FRS Software Environment which is an environment for building software for the SD cards and creating SD card images.

The SD card images include device drivers and other software for using XRS devices or FRS design. A prebuilt SD card image allows evaluation without having to setup the environment and build any software. Chapter 2 contains usage information about SD card software.

Focus on other chapters of this document is in the XRS and FRS Software Environment. It is a Debian-based Linux distribution [3] which is meant to be run using Oracle VirtualBox [7].

Chapter 3 contains information on setting up the environment.

Chapter 4 contains a usage guide for building software and images.

Chapter 5 contains a depiction of the environment components.

List of used abbreviations are in chapter 6.

List of references are in chapter 7.

Command line commands are written with `CommandLine` style. Command line commands are prefixed with either a dollar sign ($) or a hash (#), which both denote a command prompt. Commands prefixed with a hash require root privileges. Command line portions that are meant to be adapted for particular use are written in **`bold CommandLine`** style.

2 SD Card Software

Prebuilt SD card images and SD card images built by the XRS FRS SW Environment in default form contain reference software for XRS Reference Board.

The purpose of the reference software is to be able to test and demonstrate the functionality of the XRS7004E and XRS7003E devices or FRS IP. The software or parts of the software can also be licensed for customers employing XRS7000 series devices or FRS IP in their products. Main parts of the software stack are

- XR7 PTP for time synchronization
- XR7 Redundancy Supervision for HSR/PRP supervision protocol
- XR7 Management Software for configuration management and status monitoring
- System programs and utilities from Debian GNU/Linux distribution [3]
- Linux kernel
- Linux device drivers

See section 2.9 for more information on software components.

2.1 Getting XRS RPi or FRS Evaluation Board Disk Image

The reference designs files can be downloaded from Flexibilis website, http://www.flexibilis.com/products/downloads/.

The page has a download link to the ready-made RPi SD card image (“XRS RPi Disk Image”) for XRS Reference Board.

FRS Reference design (“FES Reference Design, Cyclone V SoC”) contains SD-card image in a zip file: cyclone5soc_eval\bin\xr7-frs-eval.raw.zip.

If you want to make changes to the reference design or compile it on your own, you should download the XRS FRS Software Environment which you can use to build the SD card images. See chapter 3 for more information.

2.2 Hardware Requirements

The reference software runs on Raspberry Pi 4 Model B 4 GB, Raspberry Pi 3 Model B and Raspberry Pi 2 Model B (abbreviated to RPi).

The reference software works properly only in an environment where:

- Raspberry Pi board is connected to the CPU/RPi connector of XRS Reference Board (“B” in Figure 1)
- Raspberry Pi Ethernet port is connected to XRS Reference Board Port 0 (CPU port) with an Ethernet cable. (“A” in Figure 1)

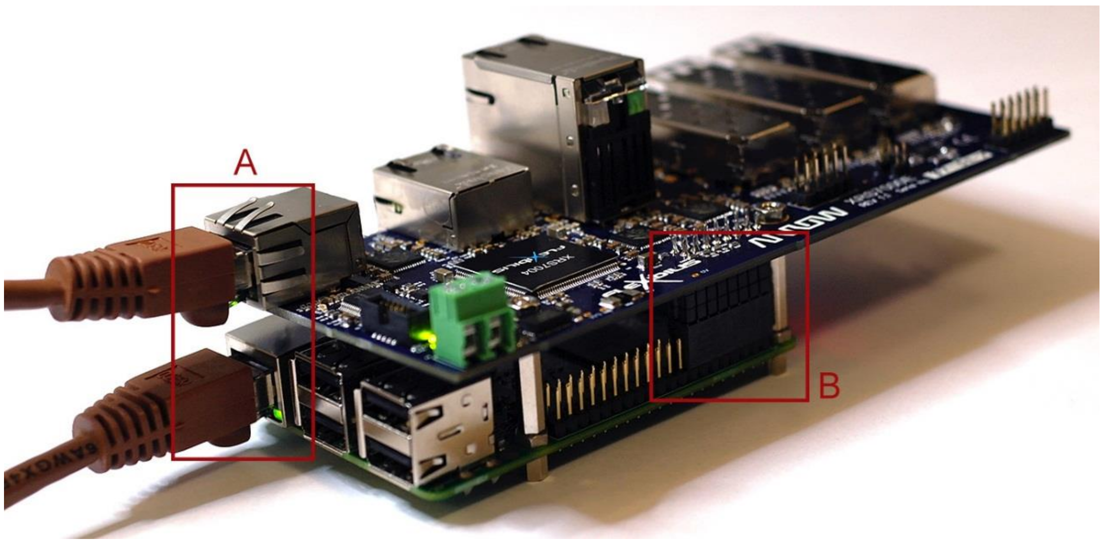


Figure 1. Raspberry Pi Connected to XRS Reference Board

Reference software uses the XRS Reference Board LEDs in a certain way which is described in Table 1. Figure 2 shows the locations of the LEDs. See SpeedChip XRS7000 Reference Board User Manual for more information [2].

LED	**Marking**	**Color**	**Usage**	**Explanation**
RJ45_0 left	-	green	Copper Eth 0 link/traffic	Lights up when link is up. Flashes when traffic.
RJ45_0 right	-	yellow	Not in use	The Reference Software does not use this LED.
Next to RJ45_0	LED14	red	Not in use	The Reference Software does not use this LED.
RJ45_1 left	-	green	Copper Eth 1 link/traffic	Lights up when link is up. Flashes when traffic.
RJ45_1 right	-	yellow	Copper Eth 1 1588_P2P	Lights up when IEEE1588 peer-to-peer communication is OK.
RJ45_2 left	-	green	Copper Eth 2 link/traffic	Lights up when link is up. Flashes when traffic.
RJ45_2 right	-	yellow	Copper Eth 2 1588_P2P	Lights up when IEEE1588 peer-to-peer communication is OK.
RJ45_3 left	-	green	Copper Eth 3 link/traffic	Lights up when link is up. Flashes when traffic.
RJ45_3 right	-	yellow	Copper Eth 3 1588_P2P	Lights up when IEEE1588 peer-to-peer communication is OK.
SFP1 green	LED16_1	green	SFP 1 link/traffic	Lights up when link is up. Flashes when traffic.
SFP1 yellow	LED15_1	yellow	SFP 1 1588_P2P	Lights up when IEEE1588 peer-to-peer communication is OK.
SFP2 green	LED16_2	green	SFP 2 link/traffic	Lights up when link is up. Flashes when traffic.
SFP2 yellow	LED15_2	yellow	SFP 2 1588_P2P	Lights up when IEEE1588 peer-to-peer communication is OK.
SFP3 green	LED16_3	green	SFP 3 link/traffic	Lights up when link is up. Flashes when traffic.
SFP3 yellow	LED15_3	yellow	SFP 3 1588_P2P	Lights up when IEEE1588 peer-to-peer communication is OK.
User LED1	LED1	green	Software blinks	Indicates that SW is running and that communication works between the boards.
User LED2	LED2	red	IEEE1588 slave	Lights up when (at least one port is) an IEEE1588 Slave and synchronized to a Master.

Table 1. Reference Software LED Usage

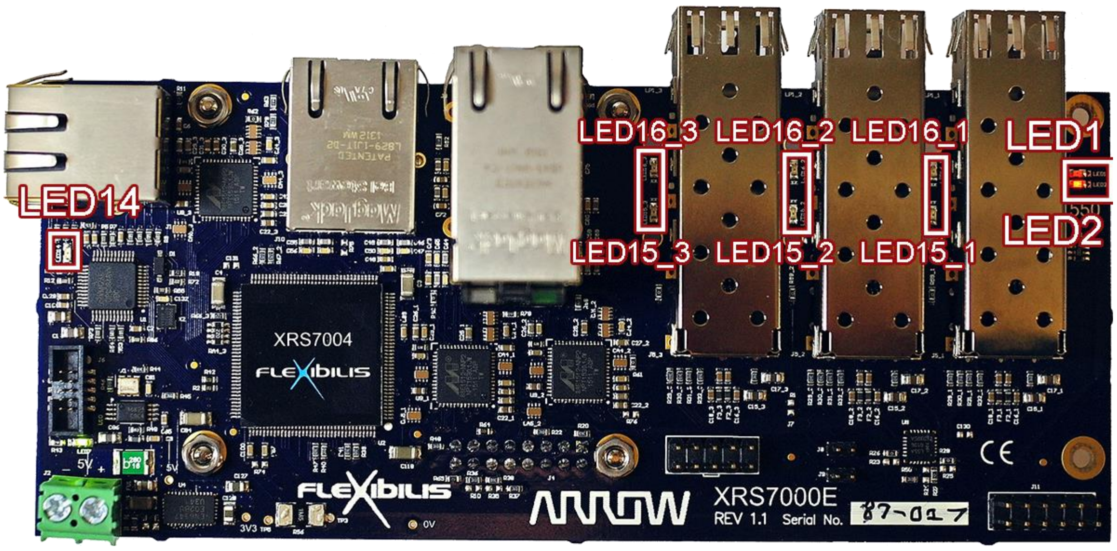


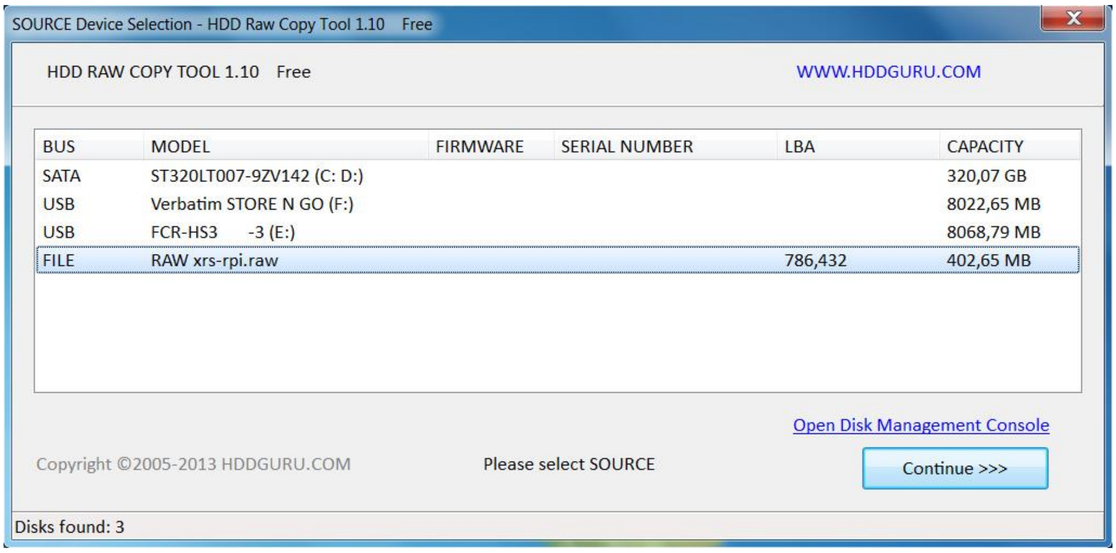
Figure 2. LED Locations

2.3 Installing Disk Image

The installation of the reference software is basically copying the Disk Image to a micro SD card. This can be done for example with a Windows or Linux PC that is equipped with an SD card reader. The recommended card size is at least 8 GB, take note also of the card class that determines transfer speed. A list of RPi compatible SD cards can be found here: http://elinux.org/RPi_SD_cards. Samsung EVO Plus microSD Memory Card 32GB was used in the testing.

2.3.1 Copying the Image on Windows

1. Point your web browser to http://hddguru.com/software/ and download the HDD Raw Copy Tool
2. Install the HDD Raw Copy Tool (Admin rights required, consult your administrator)
3. Unzip the compressed disk image if it is in compressed form
4. Use the HDD Raw Copy Tool to copy the unzipped disk image (`xrs-rpi.raw` or `xr7-frs-eval.raw`) to a micro SD card. Use the disk image file as the source and the micro SD card as the target. Be careful not to overwrite any of your hard drives! See Figure **3**.


SOURCE Device Selection - HDD Raw Copy Tool 1.10 Free

HDD RAW COPY TOOL 1.10 Free

WWW.HDDGURU.COM

BUS	MODEL	FIRMWARE	SERIAL NUMBER	LBA	CAPACITY
SATA	ST320LT007-9ZV142 (C: D:)				320,07 GB
USB	Verbatim STORE N GO (F:)				8022,65 MB
USB	FCR-HS3 -3 (E:)				8068,79 MB
FILE	RAW xrs-rpi.raw			786,432	402,65 MB

Open Disk Management Console

Copyright ©2005-2013 HDDGURU.COM

Please select SOURCE

Continue >>>

Disks found: 3

Figure 3. HDD Raw Copy Tool

5. Power off the board
6. Insert the micro SD card to the micro SD card reader
7. Power on the board

2.3.2 Copying the Image on Linux

You can use the following command:

```
$ man dd
```

Example:

```
# dd if=xrs-rpi.raw of=/dev/sdz bs=1M
# sync
# eject /dev/sdz
```

It is also possible to write the SD card image directly from within VirtualBox VM using a USB SD card reader if the VirtualBox Extension Pack has been installed. Please see the VirtualBox documentation for details. Use above Linux instructions when the USB SD card reader is detected by the VM.

Be careful not to overwrite any of your hard drives.

2.4 Accessing the Reference Design

After creating the SD card (section 2.3) and powering up your board check that a LED is blinking. In case of XRS the user LED 1 is blinking and port 0 (CPU port) link LED lights up (see Figure 2 for LED locations). Interfaces are depicted in Figure 4.

FRS SoC Eval board is presented in Figure 6.

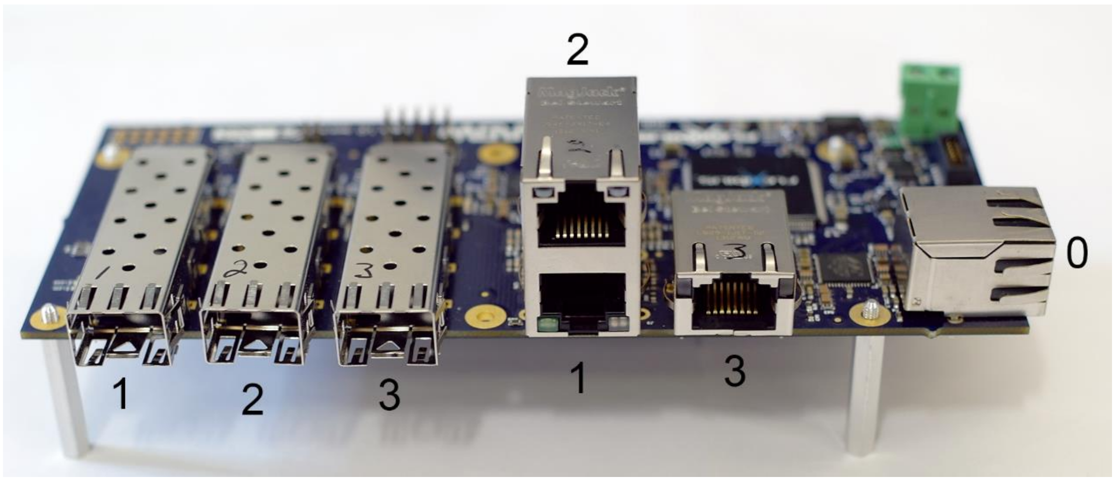


Figure 4. XRS Reference Board Interfaces

After that you can access the board with your computer by connecting to Ethernet interface 3 of the XRS Reference Board (refer to Figure 5) or interface 4 of FRS SoC Evaluation board. Any could be used, but as the first two interfaces are HSR/PRP interfaces in RedBox mode, it is usually better to use the Ethernet interface 3 or 4. The default IP address of the board is 192.168.7.1/24. Change the IP address of your computer so that it is in the same IP subnetwork – use for example IP address 192.168.7.2/24 ("/24" refers to the subnet mask and means 255.255.255.0). Factory settings are described in more detail in section 2.5.

If you create multiple SD card images for multiple reference design devices, the IP addresses should be changed to be unique before connecting them together.

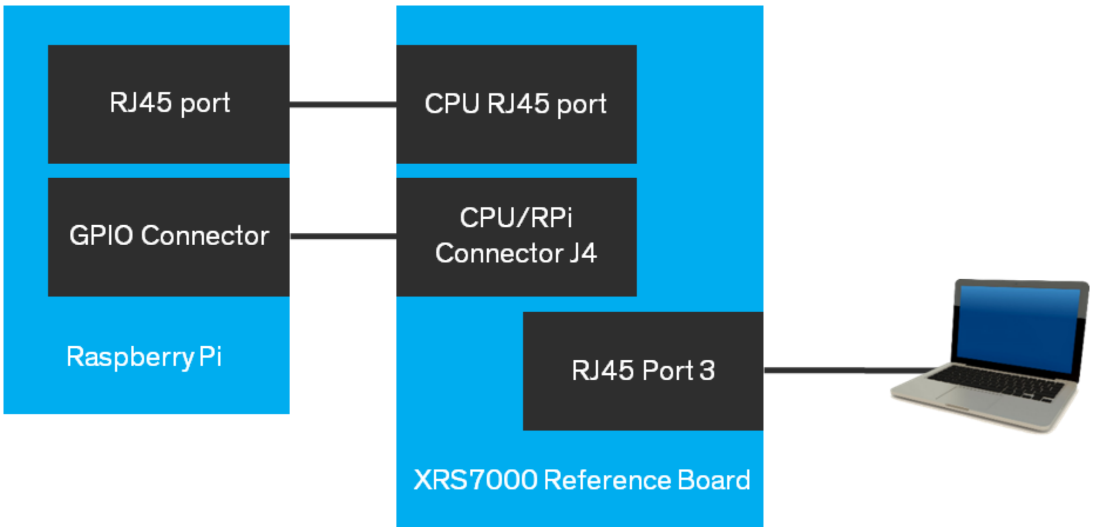


Figure 5. Accessing RPi

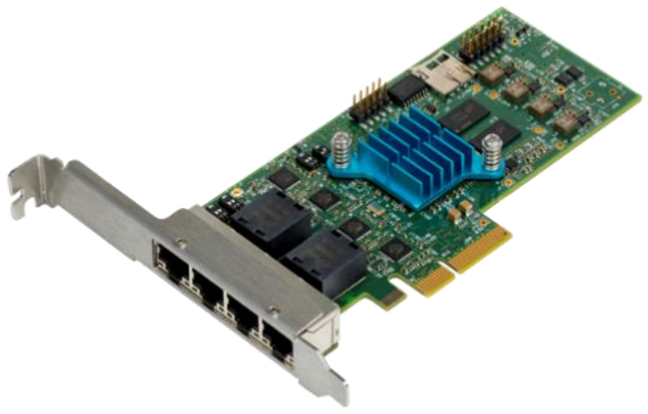


Figure 6. FRS SoC Evaluation Board interfaces are named CE01, CE02, CE03, and CE04. Interface numbering starts from left.

2.4.1 Web interface

Browse to the IP address of the board, which is http://192.168.7.1/ by default, and accept the security exceptions and warnings.

Username: admin

Password: admin

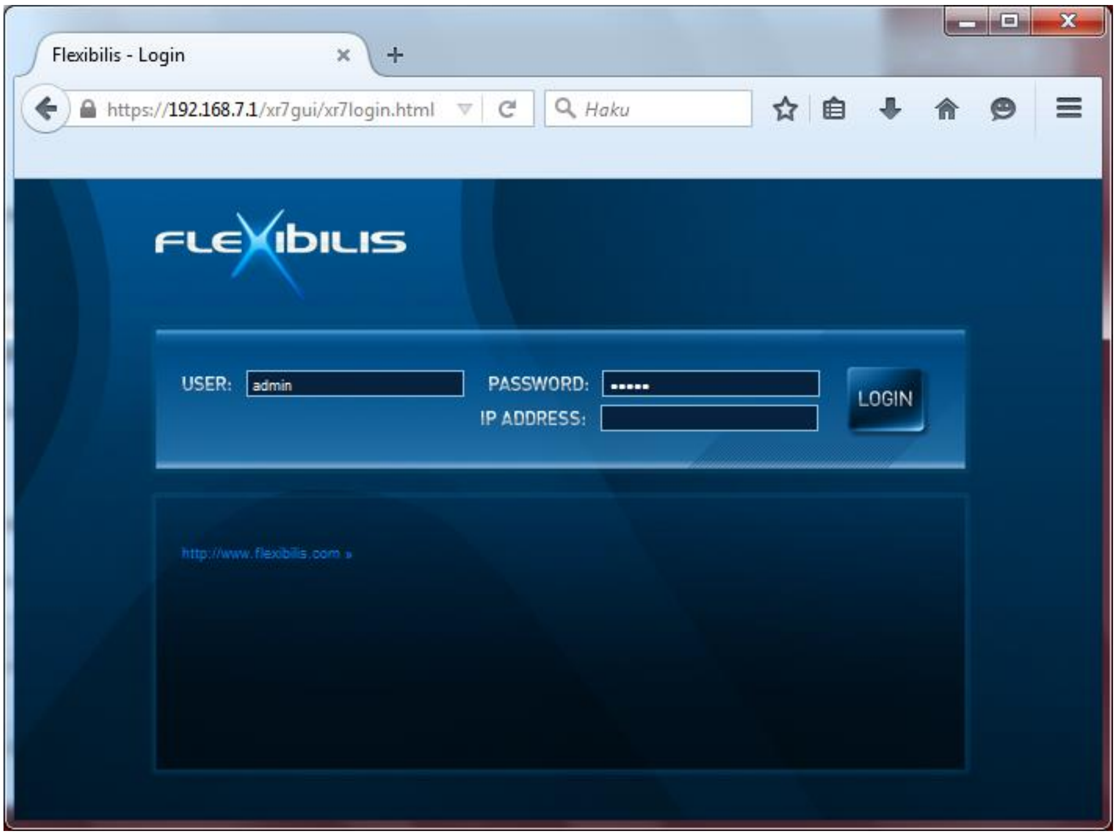
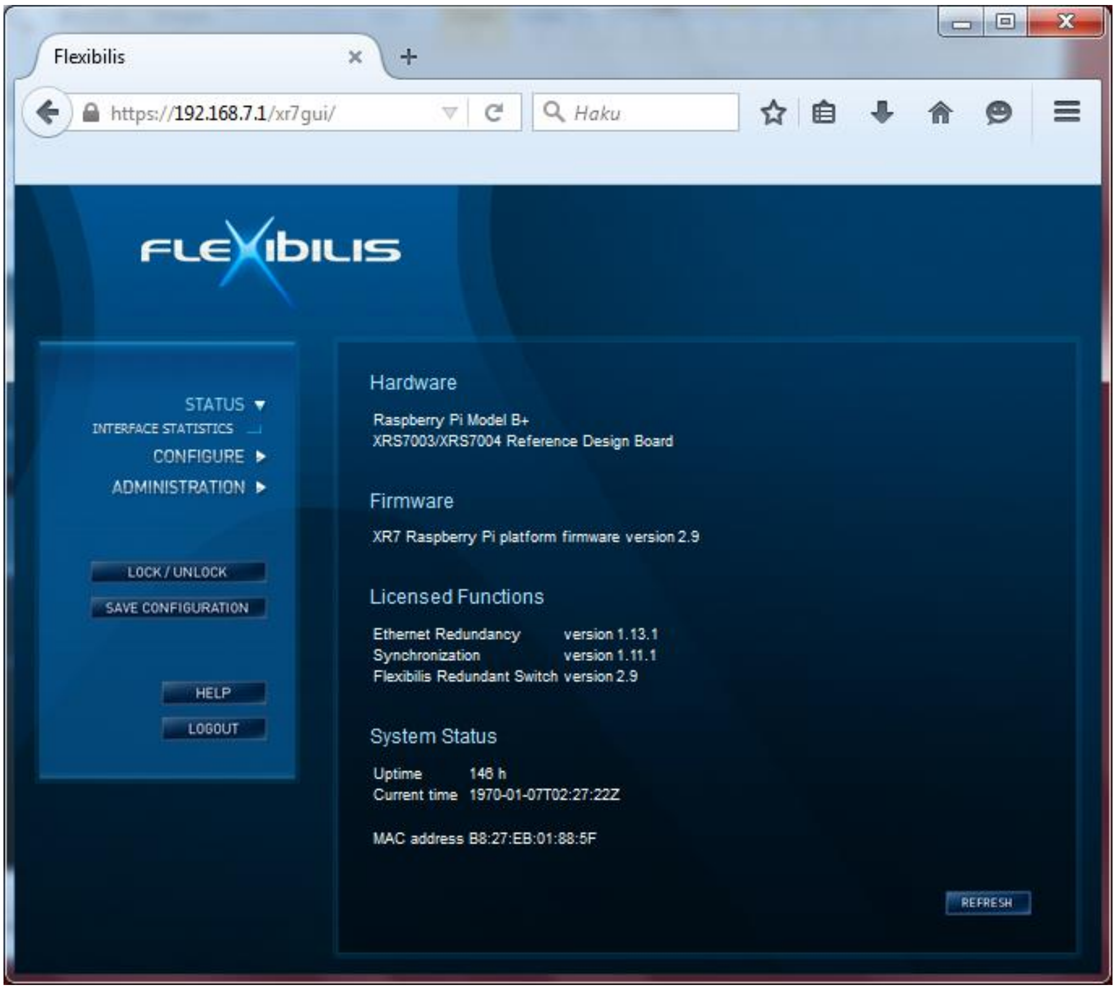

Flexibilis - Login
https://192.168.7.1/xr7gui/xr7login.html
Haku
USER:
admin
PASSWORD:
IP ADDRESS:
LOGIN
http://www.flexibilis.com »

Figure 7. Login Screen

By using the web interface (Figure 8) the user can view interface and other statistics and change different kinds of settings including IP settings, VLAN settings, interface redundancy settings and time synchronization settings.



Hardware

Raspberry Pi Model B+
XRS7003/XRS7004 Reference Design Board

Firmware

XR7 Raspberry Pi platform firmware version 2.9

Licensed Functions

Ethernet Redundancy	version 1.13.1
Synchronization	version 1.11.1
Flexibilis Redundant Switch	version 2.9

System Status

Uptime	146 h
Current time	1970-01-07T02:27:22Z

MAC address B8:27:EB:01:88:5F

Figure 8. Web Interface

2.4.2 SSH

Use your favorite SSH client (for example PuTTY) to connect to the SSH server running at RPi (the default address is 192.168.7.1). Once you have logged in you'll have a command line shell with many GNU and Linux tools available.

Username: root

Password: root

2.4.3 NETCONF

SD card software contains XR7 Flexibilis Configuration Manager (FCM), which is a NETCONF [13] agent implementation. FCM can be accessed over SSH as described in RFC 4742 [14].

NETCONF itself is not meant to be used directly as a user interface. It provides an interface for applications to manage devices by retrieving status and configuration information and uploading new configuration data.

The web interface uses NETCONF for all status information and configuration manipulation related activity. FCM module configuration files can be found from `/etc/fcmd/<MODULE>/<PROFILE>`, where `<MODULE>` is XR7 FCM module name and `<PROFILE>` is NETCONF configuration datastore name, for example `running` or `startup`.

2.5 Factory Settings

By default the SD card software for the reference design uses factory settings, which are also used when configuration is reset using the web interface (section 2.4.1). FRS and XRS reference design default settings are very similar. Below are presented XRS RPi design main characteristics of the factory configuration:

- Interfaces 1 and 2 (CE01 and CE02, respectively) are HSR redundant ports.
- Interface 3 (CE03) is used as interlink port (XRS7004).
- Switch IP address is 192.168.7.1/24.
- There are no additional static routes.
- All RS ports are members of all VLAN IDs 0 – 4095. Untagged traffic will be tagged with VLAN ID 4095 on ingress. VLAN tag of frames with VLAN ID 4095 will be removed on egress.
- PTP stack acts as a boundary clock between redundant interfaces and interlink interface (XRS7004).
- PTP stack acts as an ordinary clock with both redundant interfaces (XRS7003).
- PTP peer-to-peer delay measurement is enabled on all external interfaces.

Summary of the factory settings is in Table 2. Note that both XRS7004 and XRS7003 use the same basic configuration, but XRS7003 does not have interface CE03.

Configuration section	**Setting**	**Value**
Interface		
CE01, CE02 and CE03	Enabled	Yes
	Speed and duplex	Auto-negotiated
	Default VLAN	4095
	Default PCP	0
	VLAN Tagging	On
	Default VLAN for VLAN 0	0
	Priority for PCP 0	0
	Priority for PCP 1	0
	Priority for PCP 2	1
	Priority for PCP 3	1
	Priority for PCP 4	2
	Priority for PCP 5	2
	Priority for PCP 6	3
	Priority for PCP 7	3
Switch		
SE01	Address	192.168.7.1/24
Redundancy		
SE01	Mode	HSR
	Net ID	1
	Port S	SE01
	Port A	CE01
	Port B	CE02
	Port I	CE03
	Supervision Address	01:15:4E:00:01:00
Static Routing	Routes	(no routes)

VLAN		
VLAN IDs 0-4095	Interfaces	CE01, CE02, CE03
	Description	Default VLAN
Time Synchronization		
Interface OC01	Profile	iec_level1
	Mode	ordinary
	Delay measurement	disabled
	Ports	CE01 and CE02
Interface OC02	Profile	iec_level1
	Mode	ordinary
	Delay measurement	disabled
	Ports	CE03
Interface CE01, CE02 and CE03	Profile	iec_level1
	Mode	Transparent clock
	Delay measurement	peer-to-peer
Basic	One step / two step clock	One step clock
Clock	Class	187
	Accuracy	1 us
	Priority 1	128
	Priority 2	128
	Domain	0
	Time source	internal oscillator

Table 2. Factory Settings

Some of the settings cannot be directly changed through the web interface (section 2.4.1), though they are configuration parameters of the underlying software.

Factory settings files can be found from `/etc/fcmd/<MODULE>/factory`, where `<MODULE>` is XR7 FCM module name.

2.5.1 XRS-RPi Register Access Method

By default I²C is used to access XRS registers. This is controlled by `FLX_BUS` setting in `/etc/default/xrs` file. Reboot is needed for the change to take effect.

Change it to this for using MDIO instead:

```
FLX_BUS=mdio
```

To switch back to I²C accesses change it back to this:

```
FLX_BUS=i2c
```

The setting determines simply which one of the drivers flx_bus_i2c or flx_bus_mdio is loaded. More fine-grained control would be possible via device tree, see section 2.9.3 for details.

2.6 Source Code

Source code for some parts of the reference software, for example Linux kernel and device drivers, are available in the XRS FRS Software Environment. See section 5.1.4. On the other hand some parts of the reference software are included as prebuilt binary Debian packages in the VM package repository (section 5.1.5). To license the source codes of these binaries, please contact Flexibilis.

Used Debian software is downloaded directly from Debian servers when SD card image is built. Source code for that software is available from Debian as Debian source packages.

The reference software uses Linux kernel sources from Debian GNU/Linux distribution [3] with custom configuration. Also the RPi bootloaders are from Debian distribution package raspi-firmware.

2.7 Modifying SD Card Software

The Raspberry Pi software on SD card is based on Debian, so many of the Debian tools can be used, including `apt-get`. However prebuilt SD card images are configured to use non-public package repository servers in order to have specific, controlled versions of all software.

See section 4.3.7 for information about how to generate modified SD card images using the XRS SW Environment.

See Debian Users' Manuals [5] for more information on using and administering a Debian based GNU/Linux system.

2.8 FRS SoC Software Components

FRS SoC Eval description can be found from FRS SoC Evaluation Design Specification [19].

2.9 XRS Software Components

Important XRS SD card software components are described below, with focus on used Flexibilis software.

2.9.1 Bootloaders

XRS RPi is booted like any other Linux system on Raspberry Pi. Details vary between RPi models, see Raspberry Pi documentation for more detailed information. Bootloaders from Debian package raspi-firmware are used.

Bootloader detects RPi model and reads its own configuration files from FAT32 filesystem on SD card partition 1. Then it loads device tree, Linux kernel and initramfs image files and passes control to Linux.

RPi bootloader configuration files are in `/boot/firmware`. They are written by raspi-firmware package which has its own configuration files in `/etc/default`. So RPi bootloader configuration files should not be modified directly.

The relevant configuration files are:

`/etc/default/raspi-firmware`
: Main configuration file for raspi-firmware package. Defines root filesystem and console.

`/etc/default/raspi-firmware-custom`
: Additional configuration to pass to RPi bootloaders. Defines device tree to use for XRS chip and RPi model combination via `os_prefix` setting which is set at first boot of the SD card, along with other initial adaptations for the detected hardware.

`/boot/firmware/config.txt`
: Main RPi bootloader configuration file. File is written by raspi-firmware package.

`/boot/firmware/cmdline.txt`
: Linux kernel command line options to use. File is written by raspi-firmware package.

In order to change RPi bootloader configuration, first raspi-firmware configuration files in `/etc/default` need to be updated. Then this command can be used to make raspi-firmware update all relevant files in `/boot/firmware` for RPi bootloaders:

```
# update-initramfs -u -k $(uname -r)
```

2.9.2 Linux

Linux kernel from Debian is used. Some of the needed drivers are not included by Debian, those are built from Debian Linux kernel source package as modules. Version 5.10.0 kernel is used with all RPi models.

2.9.3 Device Tree

There is a separate device tree for all supported RPi model and XRS chip combinations. Device tree files from Debian Linux kernel source package are used for RPi devices. The XRS7000 Reference Board specific parts are in separate `.dtsi` files. A combination device tree simply includes corresponding RPi model and XRS chip device tree files. RPi bootloader is instructed to load the correct combination device tree by using `os_prefix` configuration option via raspi-firmware package.

XRS7000 registers can be accessed by either I^{2}C or MDIO. Both are connected on the XRS7000 Reference Board. In order to test both methods each XRS block with user registers appears twice in the device tree. Which one to use is selected by which one of the two drivers flx_bus_i2c and flx_bus_mdio is loaded. It would also be possible to use both, by having different devices in the two busses. See sections 2.9.4.6, 2.9.4.7 and 2.9.4.8 for driver details.

I^{2}C access is used by default because then RPi I^{2}C controller can be used to form the bus access cycles, without having to do every detail of bus access cycles in software on RPi CPU. In default form the boot script responsible for driver loading does not load the flx_bus_mdio driver.

See also Figure 9 for an illustration how the used Linux devices, busses and drivers relate to each other.

2.9.4 Drivers

Linux drivers for XRS are modular. All needed Linux drivers from Flexiblis are licensed under GPL v2. Descriptions of Flexibilis Linux drivers used in the SD card follow below.

Many of the drivers provide useful status information in own subdirectory of `/proc/driver`.

Drivers are loaded at boot time by systemd service `xr7-system`. The actual HW specific setup scripts reside in `/etc/xr7/script` and they do also some other HW related initializations in addition to just loading correct set of drivers.

Used Linux driver model busses, devices and drivers are illustrated in Figure 9. Each of the driver is described in turn.

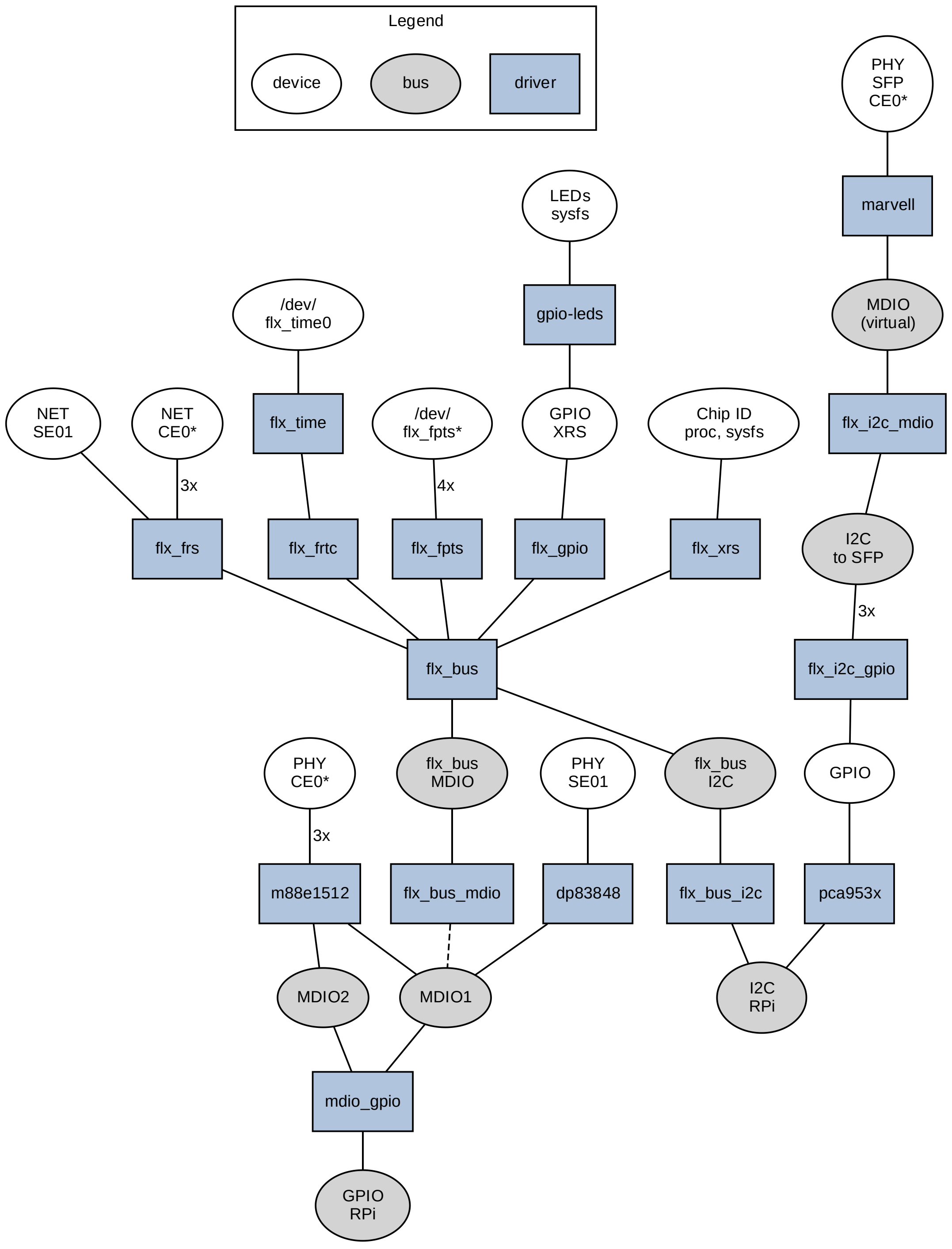


Figure 9. Drivers, Devices and Busses

2.9.4.1 flx_xrs (XRS)

Flx_xrs is a driver for XRS chip identification. It can also optionally release device from reset and enable CPU interrupt in a controlled way, but see also flx_xrs_guard driver below. Device tree bindings look like this.

```
xrs@0 {
	compatible = "flx,xrs";
	reg = <0x0 0xa>;
	/* GPIO signal for power OK, optional */
	power-ok = <&gpio 27 0>;
	/* GPIO signal for reset, optional */
	reset = <&gpio 18 0>;
	/* Interrupt to enable via sysfs, optional */
	interrupt-parent = <&gpio>;
	interrupts = <17 8>;
};
```

reg Defines register address range of XRS identification registers.

power-ok

Defines optional GPIO signal to check for power OK conditional. If this signal is not up (1), driver refuses to use that device.

This setting belongs to flx_xrs_guard when using that driver.

reset

Defines optional active low GPIO signal to use to momentarily reset the device or bring it out of reset. When driver module is removed, the reset GPIO is also freed, which asserts the reset again.

This setting belongs to flx_xrs_guard when using that driver.

interrupt-parent and interrupts

Define optional interrupt signal for controlled CPU interrupt enablement. The interrupt will be disabled first, before bringing device out of reset if also reset signal was defined. Interrupt will be enabled when readiness is signaled from user space via driver sysfs `ready` file by writing 1 to it. Readiness should be signaled when HW has been initialized correctly. This can be used to prevent killing the CPU by unconfigured HW asserting level-sensitive interrupt line.

This setting belongs to flx_xrs_guard when using that driver.

2.9.4.2 flx_xrs_guard (SoC)

This simple driver is actually part of the flx_xrs kernel module, but being a separate system driver it has its own device tree bindings. It can be used when more control is needed over bringing XRS device out of reset and enabling the CPU interrupt it is connected to.

For example when using MDIO to access XRS, the same MDIO bus might contain PHY devices and the XRS RESET_n signal which is typically connected to CPU GPIO, might control also the PHY devices. In such a situation the RESET_n must be released before MDIO bus driver (like the Linux bit-banging mdio-gpio driver) initialization. Further it may be desired to delay enabling the CPU interrupt until the PHY devices have been initialized. Otherwise a device with wrong configuration might keep the interrupt line asserted, which could easily make the very unresponsive.

Driver provides a sysfs file named `ready` which can be used to signal the driver when it is safe to enable the CPU interrupt.

Device tree bindings look like the following. Note that there is no `reg` setting. This node is typically placed inside a `soc` node, and in any case within a different node than the other XRS device nodes, like the `flx_xrs` node.

```
xrs_guard {
	compatible = "flx,xrs-guard";
	/* GPIO signal for power OK, optional */
	power-ok = <&gpio 27 0>;
	/* GPIO signal for reset, optional */
	reset = <&gpio 18 0>;
	/* Interrupt to enable via sysfs, optional */
	interrupt-parent = <&gpio>;
	interrupts = <17 8>;
};
```

power-ok

Defines optional GPIO signal to check for power OK conditional. If this signal is not up (1), driver refuses to use that device.

Do not specify this for flx_xrs when using flx_xrs_guard driver.

reset

Defines optional active low GPIO signal to use to momentarily reset the device or bring it out of reset. When driver module is removed, the reset GPIO is also freed, which asserts the reset again.

Do not specify this for flx_xrs when using flx_xrs_guard driver.

interrupt-parent and interrupts

Define optional interrupt signal for controlled CPU interrupt enablement. The interrupt will be disabled first, before bringing device out of reset if also reset signal was defined. Interrupt will be enabled when readiness is signaled from user space via driver sysfs `ready` file by writing 1 to it. Readiness should be signaled when HW has been initialized correctly. This can be used to prevent killing the CPU by unconfigured HW asserting level-sensitive interrupt line.

Do not specify this for flx_xrs when using flx_xrs_guard driver.

2.9.4.3 flx_frs (RS)

Flx_frs is a driver for FRS, FES and XRS RS (FRS is an FPGA implementation of HSR/PRP switch, FES is similar but without HSR/PRP support).

Driver creates a Linux net device for each switch port. Net devices of the external ports are attached to PHY devices, if so configured. This allows existing Linux PHY drivers to be used for link mode monitoring in order to keep RS port registers synchronized with current link mode. Link mode can be managed through ETHTOOL ioctl. Driver provides also an ioctl interface to user space for accessing RS features.

Driver needs information about each switch and switch port in device tree to function correctly. Network interface names are defined in device tree. By convention CPU ports are named SE01, SE02, and so on while external ports are named CE01, CE02, CE03 and so on, although any valid names can be used.

Switch device tree bindings are listed in the following.

reg

Address of switch registers and length in octets. Note that port registers are defined separately.

interrupts

Interrupt definition in format specific to the parent interrupt controller.

mac_name

Name of the Linux net device whose Ethernet MAC is connected to CPU port.

port<N>
: Port definitions for port number <N>.

Port device tree bindings are:

if_name
: Linux net device name for the port. Driver creates new net device for each port using this name.

medium_type
: Type of the medium used with this port. This affects how the driver deals with the port. Possible values are:

0	NONE, port is not used
1	SFP, port connected to SFP (fiber or copper) and may have a PHY
2	PHY, port hard-wired to a PHY
5	NO PHY, there is no PHY, speed can be changed at runtime

Parameters phy-handle and phy-mode must be used with SFP and PHY medium types for the RS driver to be able to attach the Linux PHY device to the RS port net device. Parameter sfp-phy-handle can be used with SFP medium type to define access to PHY within copper SFP module. Parameter sfp-eeprom can be used with SFP medium type to detect SFP type from SFP EEPROM contents.

cpu-port
: Indicates a port connected to CPU.

interlink-port
: Indicates a port connected to another FRS or RS. This is used for example when building a QuadBox using a design with one CPU and two interconnected switches.

auto-speed-select
: Configure RS port to select speed from external signals or configure XRS RS port to select speed automatically.

reg
: Address of port registers and length in octets, optionally followed by address of port adapter registers and length in octets. RS does not have adapter registers.

phy-handle
: Link to PHY device which is defined somewhere else in the device tree. This is required for ports with medium type PHY and optional for ports with medium type SFP. If this is left out, driver assumes there is no PHY.

Copper SFP modules may have a PHY, too. Parameter sfp-phy-handle should be used for them instead of phy-handle.

For medium type SFP both phy-handle and sfp-phy-handle can be specified, when there is a separate PHY in addition to SFP PHY for a port. This may be necessary for example to put both PHYs in correct mode.

phy-mode
: PHY interface mode to use with the Linux PHY driver framework. This is required when phy-handle is set. See Linux source file `drivers/of/of_net.c` for possible values.

sfp-eeprom
: Link to I^{2}C slave device of SFP EEPROM defined somewhere else in the device tree. If this is specified for ports which have medium_type value 1 (SFP), SFP module type is detected from SFP EEPROM contents. This is needed with some designs, including XRS7000 Reference Board for the port to function correctly with different SFP modules.

sfp-phy-handle

Link to PHY device within copper SFP module. Copper SFP modules typically contain a PHY device which is accessed via I^2C.

For medium type SFP both phy-handle and sfp-phy-handle can be specified, when there is a separate PHY in addition to SFP PHY for a port. This may be necessary for example to put both PHYs in correct mode.

Device tree example is shown below.

```
rs@300000 {
	#address-cells = <1>;
	#size-cells = <1>;
	compatible = "flx,rs";
	/* Switch registers */
	reg = <0x300000 0x8000>;
	interrupt-parent = <&gpio>;
	interrupts = <17 8>;
	mac_name = "eth0";
	port0 {
		if_name = "SE01";
		/* 0=none 1=SFP 2=PHY 5=NOPHY */
		medium_type = <2>;
		cpu-port;
		/* port registers */
		reg = <0x200000 0x10000>;
		phy-handle = <&xrs_phy0>;
		phy-mode = "rmii";
		/*auto-speed-select;*/
	};
	port1 {
		if_name = "CE01";
		medium_type = <1>;
		reg = <0x210000 0x10000>;
		phy-handle = <&xrs_phy1>;
		phy-mode = "rgmii-id";
		/*auto-speed-select;*/
		sfp-eeprom = <&sfp1_eeprom>;
		sfp-phy-handle = <&sfp1_phy>;
	};
	port2 {
		if_name = "CE02";
		medium_type = <1>;
		reg = <0x220000 0x10000
		phy-handle = <&xrs_phy2>;
		phy-mode = "rgmii-id";
		/*auto-speed-select;*/
		sfp-eeprom = <&sfp2_eeprom>;
		sfp-phy-handle = <&sfp2_phy>;
	};
	port3 {
		if_name = "CE03";
		medium_type = <1>;
		reg = <0x230000 0x10000>;
		phy-handle = <&xrs_phy3>;
		phy-mode = "rgmii-id";
		/*auto-speed-select;*/
		sfp-eeprom = <&sfp3_eeprom>;
		sfp-phy-handle = <&sfp3_phy>;
	};
};
```

2.9.4.3.1 Principle of Operation

Driver needs an Ethernet MAC device to work with. It catches all frames received by the MAC using Linux net device API and handles them itself. Because of this the original MAC network interface cannot be used for networking. So IP addresses and routes at OS level, for example, are configured to use the RS CPU network interface (typically SE01) instead of the original network interface.

All frames sent by OS to RS port network interfaces will be forwarded to the original MAC driver for actual sending. Before that the driver adds management trailer to all frames. Frames sent to CPU port network interface will get management trailer value zero, which causes RS to choose where to forward the frame. Frames to other port network interfaces (CExx) will get a management trailer with only the bit of that port set, causing the frame to be sent only through that port. Thus the driver relies on RS management trailer feature to work correctly.

All frames received from the MAC have the management trailer, too, which indicates the receiving external port. RS driver passes all frames to OS as coming from CPU port network interface, with the exception of HSR/PRP supervision frames and PTP frames. They are passed to OS as coming from the external port network interface so that the software can detect the original port. Because of this the external port network interfaces cannot be used for normal networking at OS level. But they can be used for link mode monitoring and enforcing a certain link mode, to retrieve port statistics counters and to access port registers.

When RS receives a PTP frame from CPU on the CPU port, it timestamps the frame and captures the frame into time stamp registers and generates an interrupt. The driver detects this and retrieves the original frame sent by software and its timestamp and passes the frame back to OS with the timestamp as coming from the first PTP enabled port. The local PTP software can detect that the frame was actually sent by itself and retrieve the PTP header information and actual send time and do corrections based on the information available. This is used for peer link delay measurement.

2.9.4.3.2 Accessing Switch Features

Driver provides an ioctl interface for accessing switch features from application code. See the driver header files for more information, files are listed in Table 3.

File	Description
Flx_frs_iflib.h	FRS specific ioctl API definitions
Flx_frs_if.h	FRS register definitions

Table 3. Flx_frs Driver API Header Files

The preferred method is to use the provided flx_fes_lib API rather than the ioctl directly. See section 2.9.5.3.

There is also a command line utility `flx_frs_tool` which supports most of the API features. Use the following command to see its usage.

```
# flx_frs_tool -h
```

2.9.4.3.3 Port Link Mode Management

Normal Linux ETHTOOL ioctl can be used to monitor and manage external port link status and mode. There is also `ethtool` command available. Example command to get CE01 port link status:

```
# ethtool CE01
```

Example command to force CE01 to 1000 Mbit/s full-duplex mode:

```
# ethtool -s CE01 autoneg off speed 1000 duplex full
```

Example command to enable auto-negotiation on CE01:

```
# ethtool -s CE01 autoneg on
```

2.9.4.3.4 Accessing Port Statistics Counters

All the statistics counters provided by RS ports are available through ETHTOOL ioctl as Linux network interface specific statistics. RS statistics counters are often much more useful than ordinary Linux net device statistics counters for diagnosing problems.

Example `ethtool` command to retrieve statistics counters for port CE01:

```
# ethtool -S CE01
```

2.9.4.3.5 Accessing MAC Address Table

Driver ioctl interface can be used to read RS MAC address table and to clear MAC address table entries of select ports.

Command `flx_frs_tool` can also be used to read the switch MAC table. Example:

```
# flx_frs_tool -m SE01
```

MAC address can be read from a proc file, too. Example:

```
# cat /proc/driver/flx_frs/device00_mac_table
```

Command `flx_frs_tool` can be used to clear switch MAC table entries of select ports. Note that it is normally not recommended for redundant ports. Example:

```
# flx_frs_tool -c CE03
```

2.9.4.3.6 Managing Port Forwarding Mode

Normally port is in disabled mode when the corresponding network interface is down or there is no link, and in forwarding mode when link is also up. Ports have also a third mode: learning.

Driver ioctl can be used to control port forwarding mode. When set in non-automatic mode, driver still keeps the port in disabled mode when network interface is down or there is no link, and in specified mode when link is up. Normal behavior can be returned by setting port back to automatic mode. This is useful for example in implementing rapid spanning tree protocol (RSTP).

Command `flx_frs_tool` can be used to control the forwarding modes. Examples:

```
# flx_frs_tool -f CE03 learning
# flx_frs_tool -f CE03 auto
```

2.9.4.3.7 Auxiliary Network Interfaces

Management trailers can be used to send frames from only select switch ports. Driver automatically creates a network interface for each port. Additional, so called auxiliary network interfaces can be created for other uses. Multiple ports can be added to each auxiliary network interface, which allows sending frames to all those ports at the same time.

Auxiliary network interfaces are used with XR7 PTP to support PTP boundary clock feature, and some other PTP usage scenarios.

Auxiliary network interfaces can be managed using the `flx_frs_tool` command. Example commands to create a new net device OC01 and add ports CE01 and CE02 to it:

```
# flx_frs_tool -A SE01 OC01
# flx_frs_tool -a OC01 CE01
# flx_frs_tool -a OC01 CE02
```

Example command to list RS ports of auxiliary network interface OC01:

```
# flx_frs_tool -l OC01
```

Example command to remove auxiliary network interface OC01:

```
# flx_frs_tool -D OC01
```

2.9.4.3.8 Independent Interfaces

As RS is basically an Ethernet switch, it forwards traffic between its ports. However it is possible to configure switch so that some of its ports appear as independent network interfaces, just like an interface of a regular Ethernet network interface card. Driver supports this use case by allowing ports to be defined as being independent interfaces.

Module parameter `ifacemodes` can be set to a bitmask, where each bit corresponds to an external port. Ports whose bit is set are treated as independent interfaces. Net devices of those external ports can then be used as if they were ordinary network interfaces. Normally a different MAC address should be set for such net devices. Command `ip` can be used for that when net device is down:

```
# ip link set dev CExx address XX:XX:XX:XX:XX:XX
```

Note that the implementation uses switch features like port forward mask, IPO rules and management trailers.

2.9.4.4 flx_frtc (RTC)

Flx_frtc is a driver for both FRTC (Flexibilis Real-Time Clock) and XRS RTC. When access to the RTC is needed from software, the device must be defined in device tree. Device tree definition looks like the following.

```
rtc@280000 {
      compatible = "flx,rtc";
      reg = <0x280000 0x10000>;
      /* Step size in nanoseconds and subnanoseconds */
      step-size = <8 0>;
};
```

reg

Address of RTC registers and length in octets.

step-size

NCO step size as two numbers: nanoseconds and subnanoseconds.
Subnanoseconds is a 32-bit number, each second is divided to 2^{32} subnanoseconds.

Driver is used from user space through the interface driver flx_time.

2.9.4.5 flx_time

Flx_time driver provides a common user space interface for all Flexibilis time related IPs and blocks, each of which has its own driver. The drivers provides character device `/dev/flx_time0`.

Driver does not have device tree bindings.

2.9.4.6 flx_bus

Flx_bus is a Linux bus driver which provides other drivers an interface for accessing device registers indirectly, i.e. without using memory mapped I/O. Actual register access methods are implemented by separate drivers which register bus interface to flx_bus driver. A Linux bus of type flx_bus is created for each such registered interface, allowing other devices to be defined in that bus and access by their drivers.

Driver itself does not have device tree bindings, but implementing drivers have. Devices which are accessed indirectly are defined as device nodes within the node implementing flx_bus.

2.9.4.7 flx_bus_i2c (XRS I²C Slave)

Flx_bus_i2c is a Linux I²C slave device driver for XRS I²C slave block. It provides access to XRS registers via I²C. It allows other drivers to use I²C to access XRS registers via flx_bus.

Because flx_bus_i2c is also a bus driver, devices which are accessed through this driver must be specified within its device node in device tree.

Following device tree example shows how this would be used within an I²C controller node with label `i2c1`, which is defined somewhere else in device tree. An `xrs` node compatible with flx_xrs driver is also shown inside `flx_bus` bus node. Note the use of #address-cells and #size-cells.

```
i2c1 {
      flx_bus_i2c: flx_bus@24 {
            #address-cells = <1>;
            #size-cells = <1>;
            compatible = "flx,bus-i2c";
            /* Possible addresses: 0x24 / 0x34 / 0x64 / 0x74 */
            reg = <0x24>;

            xrs@0 {
                  compatible = "flx,xrs";
                  reg = <0x0 0xa>;
            };
      }:
};
```

2.9.4.8 flx_bus_mdio (XRS MDIO Slave)

Flx_bus_mdio is a driver for XRS MDIO slave block. It provides access to XRS registers via MDIO. It allows other drivers to use MDIO to access XRS registers via flx_bus.

Because flx_bus_mdio is also a bus driver, devices which are accessed through this driver must be specified within its device node in device tree.

Following device tree example shows how this would be used. A `gpio` node compatible with flx_gpio driver is also shown inside `flx_bus` bus node. The bus node is defined outside of an MDIO bus, i.e. not as an MDIO bus slave. Instead the MDIO bus to use is referenced using `mdio-bus` parameter. Note the use of #address-cells and #size-cells.

```
flx_bus_mdio: flx_bus@8 {
	compatible = "flx,bus-mdio ";
	#address-cells = <1>;
	#size-cells = <1>;
	mdio-bus = <&mdio1>;
	/* Possible addresses: 0x8 / 0x9 / 0x18 / 0x19 */
	mdio-addr = <0x8>;

	flx_gpio_behind_mdio: gpio@10000 {
		compatible = "flx,gpio";
		reg = <0x10000 0x1100>;

		gpio-controller;
		#gpio-cells = <2>;
		width = <0x20>;
	};
};
```

2.9.4.9 flx_i2c_mdio (SFP PHY)

Flx_i2c_mdio is a Linux I^{2}C slave driver which turns the I^{2}C slave into Linux MDIO bus. It is used for accessing PHYs on SFP modules.

In Linux PHY devices are devices on an MDIO bus. Only such PHY devices can be attached to Linux network interface (net device). PHYs on SFP modules on the other hand are I^{2}C slave devices, a very different bus type in Linux.

Flx_i2c_mdio is an I^{2}C slave driver which creates a virtual MDIO bus on the I^{2}C bus created by any Linux I^{2}C controller driver, like the bit-banging i2c-gpio driver. It maps MDIO bus accesses to I^{2}C accesses. This allows Linux network stack to detect PHY devices automatically and to attach correct PHY driver to them. In practice most copper SFP modules include a Marvell 88E1111 PHY, which is handled by the marvell Linux driver (CONFIG_MARVELL_PHY).

A node bound to flx_i2c_mdio driver in device tree appears as an I^{2}C slave within an I^{2}C bus, and contains child nodes for PHY devices on the virtual MDIO bus.

Linux MDIO bus framework automatically scans the bus for PHY devices and uses PHY ID registers to bind the PHY devices to correct drivers. Representing them explicitly in the device tree allows to bind RS port net devices to the correct PHY device using device tree syntax.

Device tree bindings look like the following for an SFP with EEPROM and PHY in a bit-banging I^{2}C bus.

```
/* I2C bus to SFP1 */
i2c-sfp1 {
      compatible = "i2c-gpio";
      #address-cells = <1>;
      #size-cells = <0>;
      /* SDA and SCL */
      sda-gpios =
            <&ioexpand_gpio 1 (GPIO_ACTIVE_HIGH|GPIO_OPEN_DRAIN)>;
      scl-gpios =
            <&ioexpand_gpio 2 (GPIO_ACTIVE_HIGH|GPIO_OPEN_DRAIN)>;
      i2c-gpio,delay-us = <5>;
      i2c-gpio,timeout-ms = <100>;

      /* I2C slave: PHY in SFP */
      sfp1-mdio {
            #address-cells = <1>;
            #size-cells = <0>;
            compatible = "flx,i2c-mdio";
            reg = <0x56>;

            /* PHY device on virtual MDIO bus */
            sfp1_phy: sfp1-phy {
                  compatible = "ethernet-phy-ieee802.3-c22";
                  /* I2C slave address 0xac with write bit,
                   * actual I2C slave address 0x56,
                   * PHY address 0x16. Largely irrelevant though.
                   */
                  reg = <0x16>;
            };
      };

      /* I2C slave: EEPROM in SFP */
      sfp1_eeprom: sfp1-eeprom {
            compatible = "atmel,at24c01a";
            reg = <0x50>;
      };
};
```

2.9.4.10 flx_gpio (XRS GPIO)

Flx_gpio is a Linux GPIO driver for XRS GPIO block. Device tree usage looks like this.

```
flx_gpio_behind_i2c: gpio@10000 {
      compatible = "flx,gpio";
      reg = <0x10000 0x1100>;

      gpio-controller;
      #gpio-cells = <2>;
      width = <0x20>;
};
```

2.9.4.11 flx_fpts (TS)

Flx_fpts is a Linux driver for FPTS (Flexibilis PPX Time Stamper) and XRS TS blocks. It provides a character device `/dev/flx_fpts<N>` for each device where `<N>` is the device number. Character device can be read from to read events. Driver provides an ioctl interface to select mode of operation. Driver also supports select and poll system calls for event based applications.

Driver user space API is defined in driver header file `flx_fpts_api.h`.

2.9.4.12 m88e1512 (PHY)

M88e1512 is a Linux PHY driver for Marvell 88E1512 PHY device which is used in XRS Reference Board.

2.9.4.13 leds_gpio

Standard Linux leds_gpio driver is used for controlling LEDs connected to XRS GPIO on XRS Reference Board. LEDs are defined in device tree. See Table 1 for summary of the LEDs. Driver provides a sysfs based user space interface for LED control.

Note that PHY LEDs are controlled by PHY drivers.

2.9.5 User Space

The core user space environment consists of system programs, utilities and libraries from Debian GNU/Linux distribution [3]. Additional software from Flexibilis provides support for the features of XRS Reference Board and its XRS device. Those are described in the following.

2.9.5.1 XR7 PTP

XR7 PTP implements Precision Time Protocol. It is described in detail in XR7 PTP Design Specification [17]. XR7 PTP is modular software and uses dynamically linked shared object libraries on GNU/Linux systems. The following PTP modules are used in XRS Reference Software.

xr7ptp
: This is the main program (daemon) which includes the XR7 PTP library, i.e. the main functionality of the PTP stack.

os_if
: This library implements the OS interface on GNU/Linux for XR7 PTP library.

flx_frtc_clock_if
: This library implements the Clock interface for the XR7 PTP library and uses RTC as local clock. Thus when local device is a PTP slave, this library keeps local RTC time synchronized with the PTP master clock. It also enables certain features of RS. Flx_time driver user space API (ioctl) is used to access the RTC and library flx_fes_lib is used to access the RS.

flx_packet_if
: This library implements the Packet interface for the XR7 PTP library and uses RS timestamping features. Library flx_fes_lib is used to access RS.

netconf (XR7 FCM “sync” module)
: This library provides NETCONF interface to the PTP stack. It uses the Control and Configuration interfaces of the XR7 PTP library and implements XR7 FCM module API. FCM support for XR7 PTP is an optional component and requires XR7 FCM, see chapter 2.9.5.4.1 for more information.

host_clock_adj
: This is a separate daemon which keeps the OS (Linux) clock synchronized to RTC time.

2.9.5.2 XR7 Redundancy Supervision

XR7 Redundancy Supervision implements HSR/PRP Supervision protocol. It is described in detail in XR7 Redundancy Supervision Design Specification [18]. It is modular software and uses dynamically linked shared object libraries on GNU/Linux systems. Here is summary of the supervision modules used in XRS7000 Reference Software.

xr7_redundancy_supervision
    This is the main program (control daemon).

supervision_lib
    Supervision library implements the HSR/PRP Supervision protocol.

packet_lib
    Packet library provides access to the Linux network stack and interfaces. It uses library lfx_fes_lib to access RS.

netconf (XR7 FCM "redundancy_supervision" module)
    This library provides NETCONF interface to redundancy supervision. NETCONF is an optional feature and requires the XR7 FCM module, see chapter 2.9.5.4.1 for more information.

2.9.5.3 flx_fes_lib

The library contains helper functions for managing RS, FRS or FES. It is used by other software like XR7 PTP and XR7 Redundancy Supervision. The source code files are listed in Table 4.

File	Description
flx_fes.h flx_fes.c	Helper functions for configuring FRS IP and RS. Includes for example reading and writing of registers and IPO settings.
flx_fes_rstp.h flx_fes_rstp.c	Helper functions for implementing RSTP.
flx_fes_aux.h flx_fes_aux.c	Functions for managing auxiliary network interfaces.

Table 4. flx_fes_lib Files

2.9.5.4 XR7 Management Software

XR7 Management Software provides a web interface and an XML based protocol for configuring devices and examining their status. It consists of the following three parts.

2.9.5.4.1 XR7 FCM

XR7 FCM stands for Flexibilis Configuration Manager. It is an implementation of IETF NETCONF [13] network management protocol. FCM design is modular. The daemon itself implements the protocol while FCM modules, implemented as dynamically linked shared object libraries, provide NETCONF support for specific system components like XR7 PTP, XR7 Redundancy Supervision, network interfaces and so on.

FCM modules communicate with FCM using local sockets and can thus be integrated into other daemons that actually handle the tasks related to the FCM module. For example FCM module named sync implements time synchronization using XR7 PTP and runs in `xr7ptp` daemon process.

2.9.5.4.2 XR7 Interface Manager

XR7 Interface Manager (IFM) is a daemon which provides NETCONF support for various network interfaces. Its design is modular, each module is implemented as a dynamically linked shared object library with XR7 FCM module interface. The following modules are used in the XRS Reference Software.

ethernet
    This module provides Ethernet interface status and configuration for external Ethernet interfaces CE01, CE02 and CE03. For example link speed and mode can be changed or current auto-negotiation status can be retrieved. It also provides RS port statistic counters.

vlan
: This module provides VLAN configuration support for RS.

ip
: This module provides IP address configuration for the system. Note that the RS CPU port net interface is used for normal networking, so the IP address is set to that Linux network interface.

routing
: This module provides static routing configuration for the system.

2.9.5.4.3 XR7 GUI

XR7 GUI provides web interface to the device for presenting status information and for configuring the system as desired by user. It is implemented as a Java servlet and uses NETCONF to access device resources.

In XRS7000 Reference Software Apache Tomcat is used as the web server and servlet engine. User can access the GUI from address https://192.168.7.1/ (when default IP address is configured).

2.9.5.5 SSH Server

OpenSSH server is used. SSH subsystem name netconf is configured to use `fcm_manager` so that NETCONF requests over SSH are forwarded to FCM.

2.9.5.6 LED Control

XRS Reference Board LEDs are controlled either by XR7 LED Control daemon xr7_led_ctrld (XRS GPIO LEDs), or by PHY drivers (link LEDs). See Table 1 and descriptions of LEDs in XRS Reference Board User Manual.

The XR7 LED Control daemon identifies the XRS Reference Board from its XRS chip type and configures itself accordingly. It monitors the processes and XR7 PTP status from XR7 FCM and sets the LEDs according to determined system state.

2.10 Troubleshooting

This chapter describes various methods to verify and debug XRS devices and configurations.

2.10.1 Driver Loading

Flexibilis drivers are built as kernel modules which are loaded at boot time using systemd service xr7-system.

Use `lsmod` command to see list of loaded kernel modules.

2.10.2 Driver Load Verification

Flexibilis drivers typically output something to kernel ring buffer (dmesg log), when drivers are bound to devices. Use `dmesg` command after loading the drivers to see them. Remember that usually not everything output to kernel ring buffer is output to console, so it is better to the use the `dmesg` command than to rely on boot time prints on console.

Examples of such prints are:

```
flx_xrs: Init driver
flx_xrs 0.xrs: XRS7004E revision 1.0
flx_gpio: Init driver
flx-gpio 10000.gpio: Added GPIO 476 .. 495
flx_i2c_mdio: Init driver
```

```
flx-i2c-mdio 0-0056: Registering virtual MDIO bus flx-i2c-mdio-0 for
I2C slave 0x56
flx-i2c-gpio soc:i2c-sfp1: using pins 497 (SDA) and 498 (SCL)
flx-i2c-mdio 2-0056: Registering virtual MDIO bus flx-i2c-mdio-1 for
I2C slave 0x56
flx-i2c-gpio soc:i2c-sfp2: using pins 502 (SDA) and 503 (SCL)
flx-i2c-mdio 3-0056: Registering virtual MDIO bus flx-i2c-mdio-2 for
I2C slave 0x56
flx-i2c-gpio soc:i2c-sfp3: using pins 507 (SDA) and 508 (SCL)
flx_time: char dev major 248
FLX_TIME: Register NCO component(s)
flx_frtc 280000.rtc: probe device
FLX_TIME: Component  (index 0/1) registered
FLX_TIME: NCO using current time in init (11)
FLX_TIME: NCO using step size 8 ns 0 subns adjust_scale factor 34
flx_fpts: Init driver
flx_fpts 290000.ts: Setup device 0 IRQ 497 for indirect register
access
flx_fpts 298000.ts: Setup device 1 IRQ 497 for indirect register
access
flx_fpts 2a0000.ts: Setup device 2 IRQ 497 for indirect register
access
flx_fpts 2a8000.ts: Setup device 3 IRQ 497 for indirect register
access
flx_frs 300000.rs: Init device
flx_frs 300000.rs: port 0 reg 0x200000 adapter 0x0
flx_frs 300000.rs: port 1 reg 0x210000 adapter 0x0
flx_frs 300000.rs: port 2 reg 0x220000 adapter 0x0
flx_frs 300000.rs: port 3 reg 0x230000 adapter 0x0
flx_frs 300000.rs: Setup device for indirect register access
flx_frs 300000.rs: FRS IRQ 497 allocated
flx_frs 300000.rs: FRS SW reset done
flx_frs 300000.rs SE01: Link is DOWN (PORT_STATE: 0x2)
flx_frs: Flexibilis Redundant Switch (FRS) port SE01
flx_frs 300000.rs CE01: Link is DOWN (PORT_STATE: 0x2)
flx_frs: Flexibilis Redundant Switch (FRS) port CE01
flx_frs 300000.rs CE02: Link is DOWN (PORT_STATE: 0x2)
flx_frs: Flexibilis Redundant Switch (FRS) port CE02
flx_frs 300000.rs CE03: Link is DOWN (PORT_STATE: 0x2)
flx_frs: Flexibilis Redundant Switch (FRS) port CE03
flx_frs 300000.rs: Trailer length 1 offset 0 with CPU port
flx_frs 300000.rs:   Port 0 send trailer 0x0
flx_frs 300000.rs:   Port 1 send trailer 0x2
flx_frs 300000.rs:   Port 2 send trailer 0x4
flx_frs 300000.rs:   Port 3 send trailer 0x8
flx_frs 300000.rs: Ifacemodes: default
flx_frs 300000.rs SE01: Attached PHY driver [NatSemi DP83848]
(mii_bus:phy_addr=gpio-1:05)
flx_frs 300000.rs SE01: Link is DOWN (PORT_STATE: 0x806)
flx_frs 300000.rs SE01: Interface open
flx_frs 300000.rs CE01: Attached PHY driver [Marvell 88E1512]
(mii_bus:phy_addr=gpio-1:01)
flx_frs 300000.rs CE01: Link is DOWN (PORT_STATE: 0x402)
flx_frs 300000.rs CE01: Interface open
IPv6: ADDRCONF(NETDEV_UP): CE01: link is not ready
flx_frs 300000.rs CE02: Attached PHY driver [Marvell 88E1512]
(mii_bus:phy_addr=gpio-1:00)
flx_frs 300000.rs CE02: SFP type changed from NONE to 1000Base-X
flx_frs 300000.rs CE02: Link is DOWN (PORT_STATE: 0x402)
flx_frs 300000.rs CE02: Interface open
flx_frs 300000.rs CE03: Attached PHY driver [Marvell 88E1512]
(mii_bus:phy_addr=gpio-2:01)
flx_frs 300000.rs CE03: Attached PHY driver [Marvell 88E1111]
(mii_bus:phy_addr=flx-i2c-mdio-2:16)
flx_frs 300000.rs CE03: SFP type changed from NONE to 1000Base-T
flx_frs 300000.rs CE03: Link is DOWN (PORT_STATE: 0x402)
flx_frs 300000.rs CE03: Interface open
flx_frs 300000.rs SE01: Link is UP at 100 Mbps (PORT_STATE: 0xa04)
flx_frs 300000.rs: No FRS device found by trailer 0x0
flx_frs 300000.rs: Port not found for frame
flx_frs 300000.rs CE02: Link is UP at 1000 Mbps (PORT_STATE: 0x520)
flx_frs 300000.rs: No FRS device found by trailer 0x0
flx_frs 300000.rs: Port not found for frame
flx_frs 300000.rs OC01: Registered new FRS aux netdevice
flx_frs 300000.rs OC02: Registered new FRS aux netdevice
flx_frs 300000.rs CE01: Link is DOWN (PORT_STATE: 0x402)
flx_frs 300000.rs CE02: Link is UP at 1000 Mbps (PORT_STATE: 0x122)
flx_frs 300000.rs CE03: Link is DOWN (PORT_STATE: 0x402)
flx_frs 300000.rs CE01: Link is DOWN (PORT_STATE: 0x402)
flx_frs 300000.rs CE02: Link is UP at 1000 Mbps (PORT_STATE: 0x120)
flx_frs 300000.rs CE03: Link is DOWN (PORT_STATE: 0x402)
```

Many drivers also create files in `/proc/driver` for each device. Use `find` or `ls` command to see the file names and `cat` command to see their contents. Example:

```
# find /proc/driver
```

If there are no files even though driver is loaded, the driver is not bound to a device. This may mean for example a problem with device initialization.

2.10.3 Redundant Switch (RS)

RS specific troubleshooting and debug tips follow.

2.10.3.1 Switch Register Access

Use driver `/proc` files to verify that switch registers can be accessed correctly. Note that the driver uses word addresses, double the addresses to get byte addresses.

Example:

```
# cat /proc/driver/flx_frs/device00_common_registers
```

One of the first things to check in case of problems is to verify that the GENERAL register value is correct.

2.10.3.2 Port Register Access

Use driver `/proc` files to verify that port registers can be accessed correctly and are set to correct values. Example:

```
# cat /proc/driver/flx_frs/device00_port_registers

Port registers of device 0      (REG):   PORT0  PORT1  PORT2  PORT3

State                        (0x0000):   0x0204 0x0120 0x0120 0x0120
VLAN                         (0x0008):   0x8fff 0x8fff 0x8fff 0x8fff
…
```

2.10.3.3 Port Link Status and Speed

XRS and FRS SoC Reference Boards use Ethernet PHYs on all external ports (also CPU port is external in XRS case). Thus the Linux net device for such external ports, for example CE01, is attached to a Linux PHY device. This is configured in device tree and indicated in the kernel ring buffer (dmesg log) with a line like this:

```
flx_frs 300000.rs CE01: Attached PHY driver [Marvell 88E1512]
(mii_bus:phy_addr=gpio-1:01)
```

Use `ethtool` command to check the link mode:

```
# ethtool CE01
Settings for CE01:
      Supported ports: [ TP MII FIBRE ]
      Supported link modes:   10baseT/Full
                              100baseT/Full
                              1000baseT/Full
      Supported pause frame use: No
      Supports auto-negotiation: Yes
      Advertised link modes:  10baseT/Full
                              100baseT/Full
                              1000baseT/Full
      Advertised pause frame use: No
      Advertised auto-negotiation: Yes
      Link partner advertised link modes:  10baseT/Full
                                           100baseT/Full
                                           1000baseT/Full
      Link partner advertised pause frame use: No
      Link partner advertised auto-negotiation: Yes
      Speed: 1000Mb/s
      Duplex: Full
      Port: MII
      PHYAD: 1
      Transceiver: external
      Auto-negotiation: on
      Supports Wake-on: d
      Wake-on: d
      Current message level: 0x00000007 (7)
                             drv probe link
      Link detected: yes
```

Use driver `/proc/driver/flx_frs/device<NN>_port_registers` file to verify that the RS port is in correct state (forwarding state, management state, speed).

2.10.3.4 Use of Correct PHY Driver

Linux PHY framework detects the type of PHY from PHY ID registers (register numbers two and three). It uses that information to decide which of the loaded PHY drivers to use to handle the PHY device.

Many PHY devices can work with the generic PHY driver. But some PHY devices require a specific driver to work correctly. This can also depend on the HW. It is possible that on some HW design PHY can work with the generic PHY driver while on a different HW design a specific PHY driver is needed, for example if HW design is such that certain PHY specific register values must be changed from their default values.

Driver shows the name of PHY driver used for an external port in kernel ring buffer (dmesg log). Example:

```
CE01: Attached PHY driver [Generic PHY] (mii_bus:phy_addr=flx-i2c-
mdio-0:16)
```

If the link does not work with the generic PHY driver, check if the Linux kernel contains a specific PHY driver for your PHY. The PHY drivers are in `drivers/net/phy` directory in kernel source tree. Enable the relevant PHY driver in kernel configuration and ensure the module is loaded at boot time before RS driver, or build the PHY driver directly into Linux kernel. Use `dmesg` command to see that the PHY driver really accepts the PHY.

In some cases a newer Linux kernel may contain a suitable PHY driver. In other cases it may be necessary to write a new driver for the PHY.

2.10.3.5 SFP Module Change Detection

When port has been configured for medium type SFP, driver tries to detect when SFP module is changed. This might not work in all designs, because Linux PHY framework is not really designed to handle dynamically disappearing and appearing of PHY devices on an MDIO bus.

Together with flx_i2c_mdio driver SFP module change detection works. If flx_i2c_mdio is used with other drivers it may be necessary to disable this feature by this directive in device tree for flx_i2c_mdio node:

```
        disable-change-detection;
```

2.10.3.6 Traffic Problems

First check that link is up and link status is correct in all places: from PHY driver, in port state register, and also on the link partner side.

Then check port statistics counters. They are very useful in some cases to narrow down the problem, because different counters for good and bad octets and for different types of frames are available for each port and for both directions. This makes it possible to track the flow of frames from source to destination through RS and back.

Use ethtool command to see the statistics counters. Example:

```
# ethtool -S SE01
# ethtool -S CE01
```

Example scenario: Communication is attempted from CPU with another device through an RS. Frames are sent from CPU through an EMAC connected to RS CPU port. Frames are expected to be forwarded by RS from CPU port SE01 to external interface CE01 which is directly connected to the destination device. The destination device is expected to send responses back and it is expected that the responses travel the same path in the reverse order.

First ensure that there are no daemons running on either side which could generate any extra traffic and that the switch and ports are in correct state. Then start to send frames from CPU. Check that the OS actually tries to send packets to the MAC which is connected to CPU port. The transmit counters of both CPU port (SE01) and MAC net device (for example eth0) should increase without error counters increasing. Example:

```
# cat /proc/net/dev ; sleep 1 ; cat /proc/net/dev
```

Then verify that CPU port RX counters increase (rx_good_octets):

```
# ethtool -S SE01
```

Then verify that RS forwards the frames to CE01: tx_octets should increase.

```
# ethtool -S CE01
```

Then verify that the destination device receives the frames.

If everything looks good, verify that the problem is not in the other direction. Verify that destination device actually sends the responses back.

Then verify that the CE01 port receives the frames: rx_good_octets should increase.

```
# ethtool -S CE01
```

Then verify that RS forwards the response frames to CPU port: tx_octets should increase:

```
# ethtool -S SE01
```

Then verify that the frames are pass through the MAC by checking RS CPU port net device receive counters (this time SE01 only, as RS driver passes received frames always from its own net devices to OS).

```
cat /proc/net/dev
```

If frames are sent by OS towards MAC, but CPU port RX counter never increases, the problem may be related to the MAC.

If frames received on CPU port are not forwarded to other RS ports, or responses are not forwarded from external ports to CPU port, the problem may be in IPO entries or in VLAN configuration. Check also RS port forward mask register value.

If frames sent out from external port do not appear at the destination, there may be a problem with the adapter connection or PHY or with the external device. It may also be useful to test with other types of destination devices to rule out some HW interoperability problems. PHY devices may also provide useful counters or status information. Also make sure the PHY device is put in correct interface mode.

2.10.3.6.1 VLAN

One common cause of traffic problems is an error in VLAN configuration. Verify that both the port specific VLAN registers and port VLAN membership registers are set correctly. Example:

```
# cat /proc/driver/flx_frs/device00_port_registers
# cat /proc/driver/flx_frs/device00_vlan_config_registers
```

Note the use of PORT_VLAN registers for default VLAN and tagging configuration.

2.10.3.6.2 RGMII

Remember that RGMII requires clock signal delay. Many PHYs support different internal delay modes, which can be enabled using `phy-mode` parameter in device tree if the PHY driver supports it. The relevant modes are: `"rgmii-id"`, `"rgmii"`, `"rgmii-rxid"` and `"rgmii-txid"`. In some cases some other method may have to be used to ensure clock compatibility.

2.10.3.7 MTU

A management trailer is used on RS CPU port. This adds one octet, or in some setups two, to the frames sent to or received from RS CPU port. Some Ethernet MACs, like the MAC on RPi Ethernet port, may not work correctly with such Ethernet frames if the frame size exceeds the default MTU of 1500 octets (without VLAN tag).

This can be fixed by decreasing MTU of RS port network interfaces accordingly. XRS Reference SW init script does this automatically. Command to do this is

```
ip link set dev IFACE mtu 1498
```

where `IFACE` is the Linux network interface name (SE01, CE01, etc.).

2.10.4 RTC

A few checks for RTC follow.

2.10.4.1 Checking RTC Is Running

Use `/proc/driver/flx_time/component_<NN>_registers` file to see RTC register values. `<NN>` is flx_time index number of the clock, starting from 00. Example:

```
# cat /proc/driver/flx_time/component_00_registers

Component index: 0
 name           : Local NCO
 device id      : 0x0090
 revision id    :   0x02
 properties     :   0x1f

 Time read:
  seconds       : 137409
  nanoseconds   : 434575818
  subnsecs      : 0x0000
  clk cycle cnt: 0x00000f9f29d35bf1

 Register content:
  nco subnsec reg       :     0x00000000
  nco nsec reg          :     0x19e719ca
  nco sec reg           : 0x0000000218c1
  nco cccnt reg         : 0x0f9f29d35bf1
  nco step subnsec reg :     0x00000000
  nco step nsec reg     :           0x08
  nco adj nsec reg      :     0x1614ecf2
  nco adj sec reg       : 0x000000000012
  nco cmd reg           :           0x00
```

By default RTC step size register values can be zero. When RTC driver is loaded, it writes configured nominal step size value to the step size registers and RTC starts running. Check that seconds and nanoseconds values increase.

2.10.4.2 Rough Frequency Check

Get RTC register values at for example ten seconds apart and compare elapsed time to wall clock time. Example:

```
# (cat /proc/driver/flx_time/component_00_registers ; sleep 10 ; cat
/proc/driver/flx_time/component_00_registers) | grep seconds
  seconds       : 137739
  nanoseconds   : 771582498
  seconds       : 137749
  nanoseconds   : 778224842
```

Note that if OS clock does not run at correct frequency, actual time between above prints may deviate a lot from ten seconds wall clock time. Calculate elapsed RTC time and divide it by elapsed wall clock time. The result should be close to one.

If RTC does not run at roughly the correct frequency, check that the nominal step size value is configured correctly.

3 XRS and FRS SW Environment Setup

This chapter describes how the XRS and FRS Software Environment can be set up for the first time.

3.1 Getting the SW Environment

To download the XRS and FRS Software Environment, please fill in the form on our website http://www.flexibilis.com/products/downloads/, and we will give you access to download the XRS and FRS SW Environment.

The delivery package contains the following:

- Release note document
- XRS and FRS Reference Software User Guide document
- Virtual machine disk image including the XRS and FRS Software Environment

3.2 Introduction to the Environment

The environment contains all necessary tools pre-installed for building and managing software and SD card images. Build processes are highly automated so that new and custom images can be built with minimum effort.

An included build environment provides a cross-compile tool chain for Raspberry Pi and for FRS SoC design. The tool chain is used to build binary packages for the resulting SD card images.

There are separate users for the Raspberry Pi and FRS SoC development. `xrs` user environment is set so that it creates Raspberry Pi images. `frs` user is intended for FRS SoC images.

The environment is used either with a continuous integration server (see 5.1.2 for more information) or with command line via SSH. The environment does not provide a graphical desktop environment.

Main components of the environment are depicted in Figure 10. More information on the components can be found in chapter 5.

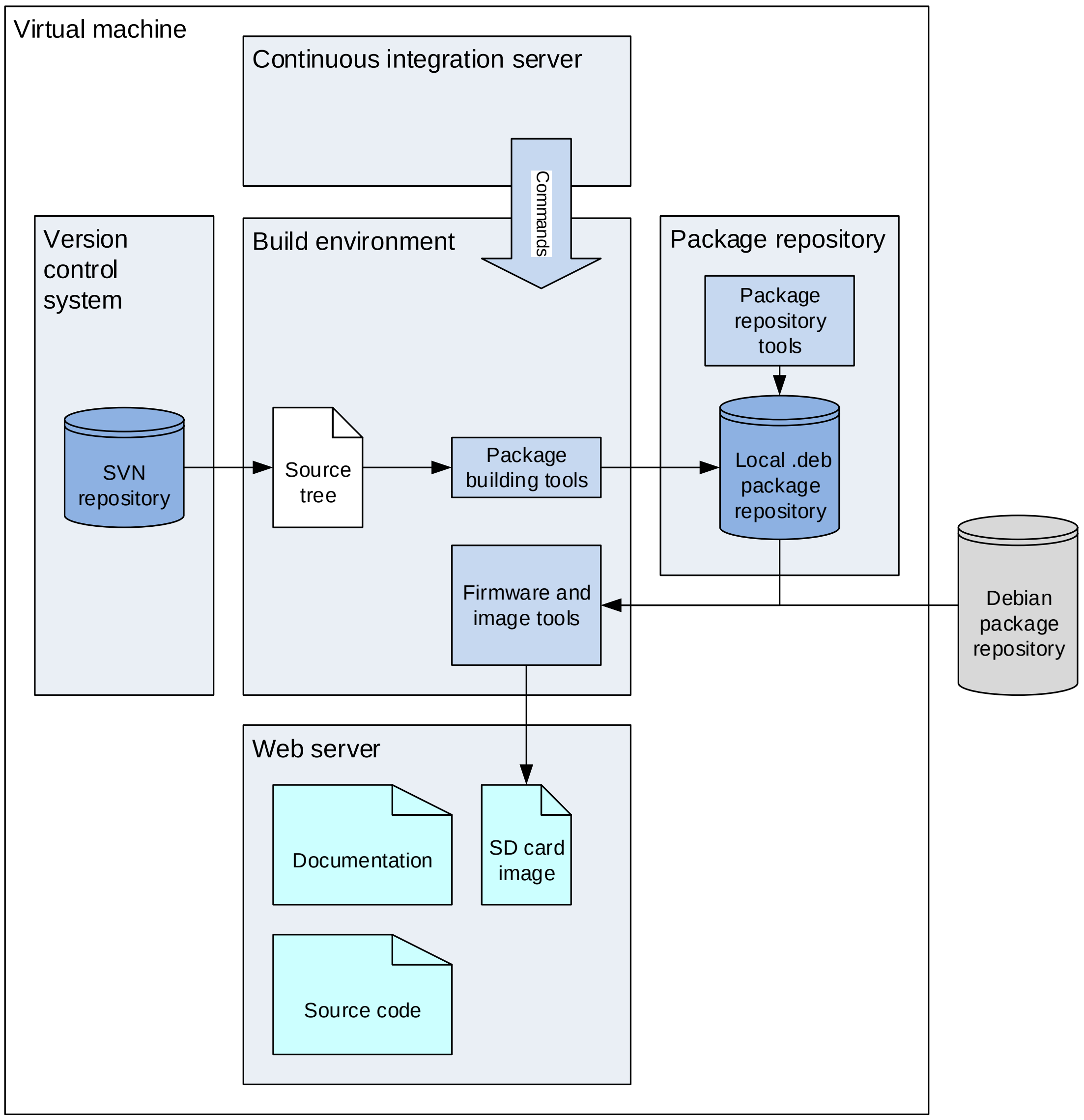


Figure 10. Environment Components

3.3 Setting up New Virtual Machine

In order to start using the SW Environment, a virtual machine must be set up to boot and run the virtual machine disk image provided by Flexibilis.

A virtual machine can be created with Oracle VM VirtualBox Manager Software. It is open source and can be downloaded from here: https://www.virtualbox.org/. You can find documentation for the software on the same site [15].

3.3.1 Networking

Before creating the virtual machine, it's good to verify that the host computer has internet access. The virtual machine must have network connectivity. You can access some web sites with your favorite browser to check that at least DNS and HTTP are working.

Needed network accesses to the virtual machine for each provided service are listed in Table 5.

Service	Protocol: Port	Description
Jenkins CI server [8]	TCP: HTTP (8080)	Jenkins CI server is used as an interface for building software and images.
Nginx HTTP server [9]	TCP: HTTP (80)	HTTP server is used to serve built image files, documentation and source code. It can also be configured for other use.
Login	TCP: SSH (22)	Needed for command line usage and VM management tasks.

Table 5. XRS FRS SW Environment Inbound Networking Requirements

The XRS SW Environment machine itself also needs network access to outside. These outbound networking requirements are listed in Table 6.

Service	Protocol: Port	Description
DNS	UDP: DNS (53) TCP: DNS (53)	Used to query IP addresses for host names from DNS server.
NTP	UDP: NTP (123)	Used to keep environment machine system time synchronized to external NTP servers.
Package repository access	TCP: HTTP (80)	This is required to be able to access Debian package repository on the internet. Full list of possible mirrors can be found from [4]. The default is deb.debian.org

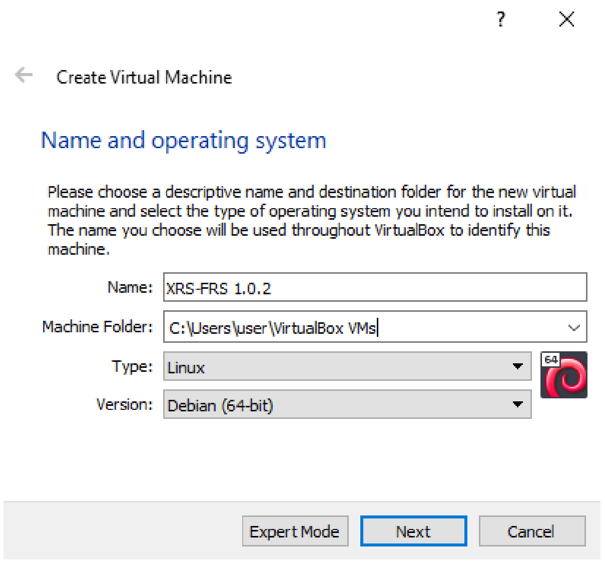
Table 6. XRS FRS SW Environment Outbound Networking Requirements

By default, a NAT style network interface with port forwarding is assumed and DHCP is used to get IP address, default route and DNS name server. A different networking setup may also require adaptation in the VM.

3.3.2 Creating VM with Virtual Box

After downloading the virtual machine disk image and installing Oracle VM VirtualBox, open the VirtualBox software and click “New”.

Give the machine a name and then choose Linux as the type and Debian (64-bit) as the version. For an example, see Figure 11.



Create Virtual Machine

Name and operating system

Please choose a descriptive name and destination folder for the new virtual machine and select the type of operating system you intend to install on it. The name you choose will be used throughout VirtualBox to identify this machine.

Name: XRS-FRS 1.0.2

Machine Folder: C:\Users\user\VirtualBox VMs

Type: Linux

Version: Debian (64-bit)

Figure 11. Virtual machine create dialog

3.3.2.1 Base Memory

The amount of memory (RAM) is one of the factors affecting how fast the virtual machine will compile the designs. At least 4 GB is recommended for smooth usage. Because the VM does not have a graphical desktop it will also work with much less but with small memory the compilation might take more than an hour. However, other factors will also affect the speed.

3.3.2.2 Main and Home Disks

Main disk is provided with the delivery package in VDI format. While creating a new machine, the VirtualBox will ask if you wish to add a virtual hard drive. Change the option to “use an existing virtual hard drive file” and choose the virtual machine disk image provided by Flexibilis, `xrs-frs-sw-environment.vdi`. You can then click “create”.

The main disk contains a single partition and a root filesystem on it. The disk in its delivery form does not contain enough free space for normal use, so more disk space must be made available for the VM. The XRS SW Environment adapts available storage for its use automatically on first boot.

Required extra disk space depends on use. One can get started with as low as 10 GB, but it is recommended to reserve space more generously right at the beginning.

The main disk size should be increased before the first boot. See section 4.3.9 for information about increasing it later.

To increase main disk space in Windows command prompt (one long line):

```
$ "%VBOX_MSI_INSTALL_PATH%\VBoxManage.exe" modifyhd
      xrs-frs-sw-environment.vdi --resize SIZE
```

SIZE is in megabytes. The environment requires SIZE to be more than 4000 MB for the disk to be adjusted at first boot.

Additionally an empty secondary disk is recommended. This might make the virtual machine faster. If available, it will be used as `/home` and for data storage for certain services. The home disk can be added from Settings > Storage > Controller: SATA > Add Hard Disk after creating the virtual machine.

It is recommended to provide two disks: a separate home disk with for example 8 GB or more space and additionally increase the main to 8 GB.

3.3.2.3 VM Settings

Before starting the VM for first time, you need to adjust some settings. Choose the VM you just created, go to Settings and change them to match these:

- General
  - Basic
    - Type: Linux
    - Version: Debian (64-bit)
- System
  - Motherboard
    - Base Memory: (≥ 2 GB recommended)
    - Boot Order: Hard Disk (disable others)
    - Extended Features:
      - Enable IO APIC: yes
      - Enable EFI: no
      - Hardware clock in UTC time: yes
  - Processor
    - Processor(s) (≥ 2 recommended)
  - Display
    - Remote Display

            - Enable server: yes (recommended for headless setups)
  - Storage
    - Controller: SATA
      - Type: AHCI
      - Use host I/O cache: no
      - Port Count: 2
      - Disks
        - xrs-frs-sw-environment.vdi SATA Port 0
        - xrs-frs-sw-environment_home.vdi SATA Port 1 (optional, recommended)
  - Audio
    - Enable Audio: no
  - Network
    - Adapter 1: (depends, see below)
      - Enable Network Adapter: yes
      - Adapter Type: Paravirtualized Network
      - Cable connected: yes

Note that certain combinations may require virtualization options (look for VT-x and VT-d) to be enabled in PC BIOS settings. The VirtualBox will notify you if BIOS settings need to be changed. You can access your computer's BIOS settings when you start the computer: during the startup, there should appear a screen that indicates what button to press to get to the BIOS menu (usually F1, F2, F10, DEL or ESC). Some systems may have a dedicated button. You need to do it before the BIOS hands the control over to the operating system.

3.3.2.4 VM Networking Settings for NAT Networking

NAT networking with port forwarding can be used and may allow also other hosts to access the VM, depending on host firewall configuration. Without port forwarding the only way to access the VM is VirtualBox console, no inbound network access would be possible. Note that firewall configuration may need changes for this to work.

In order to use NAT networking setup with port forwarding, configure network adapter as follows in the VirtualBox GUI (Settings > Network > Adapter 1 > Advanced > Port forwarding):

- Network
  - Adapter 1
    - Enable Network Adapter: yes
    - Attached to: NAT
    - Adapter Type: Paravirtualized Network (virtio-net)
    - Cable connected: yes
    - Port Forwarding: (See Table 7)

Name	Protocol	Host IP	Host Port	Guest IP	Guest Port
SSH	TCP		22		22
HTTP	TCP		80		80
Jenkins	TCP		8080		8080

Table 7. Sample VirtualBox Port Forwarding Configuration

Note that Guest IP must be set to value configured within VM if DHCP is not used. Note also that on multi-homed host it may be necessary or desirable to configure Host IP.

Port forwarding does not work if something on host is already listening to defined host port. In that case use a different value for host port and remember to adapt addresses used later in this document accordingly. Netstat command can be used to verify currently used addresses and ports.

```
$ netstat -na
```

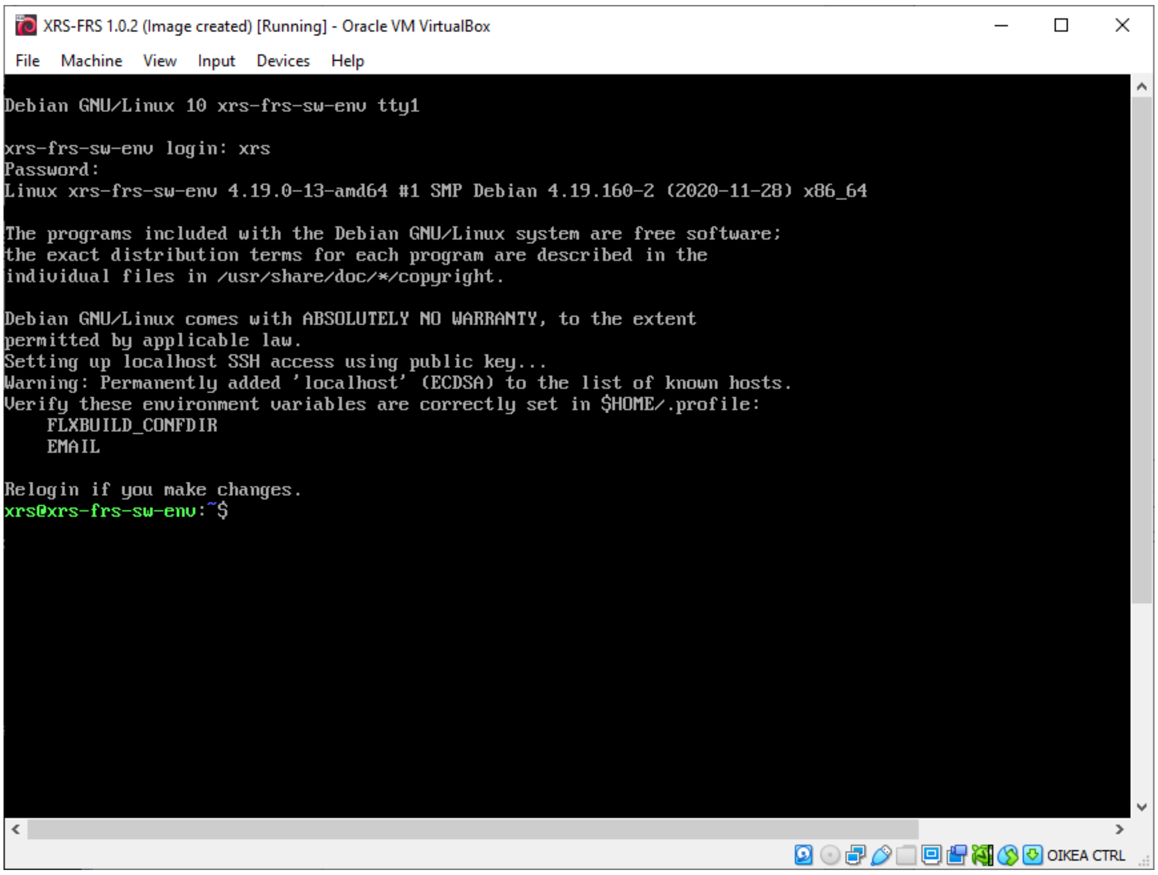
For example if port 8888 is used instead of port 80 for host port, URL http://localhost/ on host would transform to http://localhost:8888/.

Note that different software may be listening to IPv4 and IPv6 addresses on the same port number. That is one reason why 127.0.0.1 may in some cases work differently than localhost.

On Windows machines `http.sys` is typically listening to TCP port 80. It may also be possible to control it using `netsh http` command with administrator privileges.

3.4 Common Machine Settings

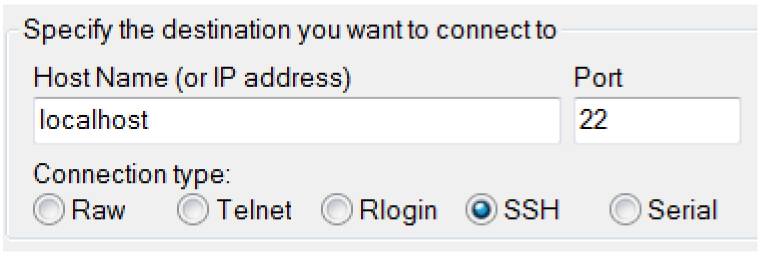
These settings are applied within the VM, so start it now. The system may restart itself a couple of times when it adapts itself on first boot. Wait for login prompt and proceed with the following on using either SSH or system console (see Figure 12). For system accounts and passwords, see chapter 3.4.1.


XRS-FRS 1.0.2 (Image created) [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
OIKEA CTRL

```
Debian GNU/Linux 10 xrs-frs-sw-env tty1

xrs-frs-sw-env login: xrs
Password:
Linux xrs-frs-sw-env 4.19.0-13-amd64 #1 SMP Debian 4.19.160-2 (2020-11-28) x86_64

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
Setting up localhost SSH access using public key...
Warning: Permanently added 'localhost' (ECDSA) to the list of known hosts.
Verify these environment variables are correctly set in $HOME/.profile:
    FLXBUILD_CONFDIR
    EMAIL

Relogin if you make changes.
xrs@xrs-frs-sw-env:~$
```

Figure 12. VM System Console

After logging in to the virtual machine, you can login with SSH by using an SSH client (for example PuTTY) on the host computer. If port forwarding was configured earlier, write “localhost” to the host name – see Figure 13.


Specify the destination you want to connect to

Host Name (or IP address): localhost

Port: 22

Connection type: Raw Telnet Rlogin [✓ SSH] Serial

Figure 13. Connecting to the VM with SSH

A lot of the information in Debian Users' Manuals [5] are also valid for XRS SW Environment because it is based on Debian.

If you just want to build an SD card image using default VM and networking configuration, it is not necessary to do any further configuration. In that case you may proceed directly to chapter 4.

3.4.1 System Accounts and Passwords

Two non-root user accounts suitable for evaluation exist in the system by default: xrs for XRS evaluation with RPi, and frs for FRS Evaluation card. Default password for these accounts is the same as account name. Change the password to your liking with `passwd`.

Default root password is "root". It can be changed the same way by logging in as root. Note that actual work using the environment should be done as a non-root user.

```
$ passwd
```

Local package repository uses its own system account flxrep whose default password is "flxrep". SSH is used locally to publish built binary packages to the local package repository.

System sets up public key SSH access for local non-root users so that packages can be published without having to type the password each time. For this reason flxrep account password is asked on first non-root user login.

Name	**Password**	**Use**
root	root	administration (only)
xrs	xrs	normal operation, preconfigured for XRS with RPi
frs	frs	normal operation, preconfigured for FRS Evaluation card
flxrep	flxrep	package repository

Table 8. Default System Account Passwords

3.4.2 Text Editors

Some of the tasks may require editing text files. The following text editors are available: `vim`, `emacs` and `nano`.

Be careful not to wrap long lines to multiple lines inadvertently. With `nano` it is often a good idea to use the `-w` option.

3.4.3 Keyboard Layout

Default keyboard layout is US American. Use the following command as root to change it.

```
# dpkg-reconfigure console-data
```

Note that the keyboard layout affects only the system console, not SSH connections.

3.4.4 Networking

Network interfaces are configured in files under `/etc/network/interfaces.d`. See Debian documentation for details. File format is described also on its manual page which can be read by

```
$ man 5 interfaces
```

No changes are needed when using the default networking setup.

3.4.5 Time Zone

The time zone is set by default to Europe/Helsinki. Use the following command as root to select a different time zone:

```
# dpkg-reconfigure tzdata
```

3.4.6 Synchronizing System Clock with NTP

Environment uses systemd-timesyncd for synchronizing system time to NTP servers. See its documentation for information on its configuration. Following command can be used to check current synchronization status:

```
# timedatectl status
```

It is important to keep the environment machine system time synchronized.

3.4.7 Adjusting Screen/Terminal Size

Environment uses GNU GRUB [16] by default to set the resolution of the terminal. In order to change the default mode, edit `GRUB_GFXMODE` setting in `/etc/default/grub` and run commands

```
# update-grub
# reboot
```

as root user. Note also the setting `GRUB_GFXPAYLOAD_LINUX=keep` which causes Linux to use the mode set by GRUB. For experimenting it may also be useful to set `GRUB_TIMEOUT` to a nonzero value (unit is seconds). See GNU GRUB [16] documentation for more information.

4 XRS and FRS SW Environment Usage Instructions

This section contains list of instructions to follow to get started with the environment. VM must be set up and running as described in chapter 3. These examples are for XRS, but the same works for FRS Evaluation, too. Just login as user frs instead.

4.1 Building Software and SD Card Images

Use either CI server or command line interface.

4.1.1 Using CI Server

The included Jenkins CI server [8] has a pre-installed job for building an SD card image for Raspberry Pi.

Navigate your web browser to http://localhost:8080 (or the address you configured for the virtual machine) and either click the schedule a build button on the right side of the Raspberry Pi SD card image job, or click on the job and select “Build Now” from the left side of the screen.

The job does the same procedure described in section 4.1.2, but in addition it copies the resulting image under the web server’s images directory. It can be found with a web browser in http://localhost/images/ (again adapt if necessary to match networking configuration).

4.1.2 Using Command Line Tools

It is recommended to use an SSH client rather than the system console as that is usually more convenient. Login as user xrs (Table 8).

A Raspberry Pi SD card image can be built by a single command:

```
$ flxb buildimage
```

The result is a raw image file, `xrs-rpi.raw` (`xr7-frs-eval.raw` for FRS Evaluation). The image file contains a fully functional system for a Raspberry Pi device, and can be written to an SD card. The file goes to the user folder, for example to `/home/xrs`.

The buildimage command does the following:

- Compiles software packages from version control repository
- Publishes new software packages to package repository
- Builds an SD card image with newest packages

You can transfer the file from the virtual machine to your host computer for example by using an SCP client like WinSCP. Connect to “localhost”, login as xrs and then transfer the file.

4.2 Importing Source Code

For example in case of a new source code release from Flexibilis, the new software should be imported to the environment to include the latest release in the SD card images.

For the default Subversion [10] repository layout, see section 5.1.4. Below examples assume that the SVN repository has been checked out to `$HOME/svn/src`, which can be done by

```
$ cd $HOME
$ mkdir svn
$ cd svn
$ svn checkout svn+ssh://localhost/home/svn/src
```

In the following example a driver release is imported. First copy the release package to the system and extract it in a temporary directory:

```
$ unzip xr7_drivers-V1.14.zip
```

Then from the extracted location, find the source package directory. It is the one with a `debian/` directory for building it as a package. Then import the source package directory under `branches` with a version number (in this case 1.14):

```
$ svn import xr7_drivers \
      svn+ssh://localhost/home/svn/src/branches/xr7_drivers-1.14
```

Now the files extracted from the release .zip file can be removed from the temporary directory.

If there are no modifications to the trunk version, it can be replaced with the new release.

```
$ cd $HOME/svn/src
$ svn update
$ svn rm trunk/xr7_drivers
$ svn commit -m "Delete old version of xr7_drivers"
$ svn copy branches/xr7_drivers-1.14 trunk/xr7_drivers
$ svn commit xr7_drivers -m "Add xr7_drivers 1.14 to trunk"
```

Now the new release is committed to the Subversion repository and it is available for the build tools to be built as a binary package and included in SD card images.

If sources in the trunk have been modified, the modifications must be merged to the new release. Merging changes to a new release is outside of the scope of this document.

See also section 4.3.7 for information how to manage which software packages are built and how the system finds them.

4.3 Advanced Usage

While `flxb buildimage` command does a lot of operations in one go, the different phases can also be invoked individually. This is very useful when the environment is used actively. This section describes some of the possibilities. See also `flxb` command online help:

```
$ flxb | less
```

4.3.1 Recreate Build Environment

Packages are built in a separate build environment in such a way that master build environment is not changed during the package build process. Command `flxb buildimage` automatically creates or updates the master build environment, but sometimes it may be desirable to just force regeneration of the build environment. The command is

```
$ suflxb buildenv
```

4.3.2 Build Individual Package

During development it is often useful to be able to build a single package, maybe even without first committing it to VCS. Run the following command from package working copy directory.

```
$ flxb build
```

There are two forms of packaging: DEBIAN/ and debian/. The former is for very simple packages that do not need any compilation phases nor separate build environment, the latter for normal packages. The files are described in Debian Policy Manual [6].

4.3.3 Install Individual Package

A single package built by `flxb build` command can be installed over SSH to target system. Network connection from VM to the Raspberry Pi device is naturally needed. The command is

```
$ flxb debinst host=X.Y.Z.W
```

where X.Y.Z.W is the IP address of the Raspberry Pi device.

4.3.4 Publish Individual Package

This command publishes a package built by `flxb build` command to local package repository. Note that all source changes must be committed to VCS first.

```
$ flxb publish
```

4.3.5 Build and Publish All Packages

This command builds and publishes all packages which are not up to date in the local package repository. SD card image is not generated.

```
$ flxb multipublish
```

4.3.6 Build SD Card Image Only

The following commands use packages already in package repository to create SD card image file, skipping the package up-to-date check and rebuild phases.

```
$ suflxb firmware
$ suflxb install
```

An alternate name for the image file can be given by `dev` parameter at install phase. Example:

```
$ suflxb firmware
$ suflxb install dev=xrs-rpi-test.raw
```

Compressed images can be created by appending suffix of the compression method to the image file name. Example:

```
$ suflxb firmware
$ suflxb install dev=xrs-rpi-test.raw.zip
```

4.3.7 Customizing Generated SD Card Images

Command `flxb buildimage` uses a text file to determine which software packages to build. It is possible to modify that list, for example to add own custom software or sources of obtained Flexibilis software releases.

However that list does not directly affect which packages are installed on SD card images. See below.

4.3.7.1 About Environment Configuration

A lot of the environment operations are defined in configuration files. By default the XRS SW Environment uses provided sample configuration that is not meant to be modified. However a copy of the configuration is available in local VCS repository directory `trunk/platform-config`, see section 5.1.4. Configuration is split into multiple files, for example main Debian mirror [4] is selected by setting MIRROR in file `base`, APT sources for SD card software in file `apt-sources`, and APT sources for build environment in file `apt-sources.buildenv`.

In order to use the VCS version of the configuration, environment variable FLXBUILD_CONFDIR must be set to absolute path to checked out working copy of the configuration directory. Following example assumes that the whole Subversion repository has been checked out in `$HOME/svn/src`, in which case the configuration can be found from `$HOME/svn/src/trunk/platform-config`. The configuration can be edited in there as needed.

```
$ export FLXBUILD_CONFDIR=$HOME/svn/src/trunk/platform-config
```

Note that the environment variable must be reset after each login. This can be done automatically by adding the export command to `$HOME/.profile`.

4.3.7.2 List of Packages to Build

The package list is configured in `$FLXBUILD_CONFDIR/batch/testing.def`. The format is described in flxb online help.

```
$ flxb | less
```

Search for “batch operations”.

4.3.7.3 Adding Packages to SD Card

Packages to install are determined from package dependencies. Meta package xr7-rpi-custom is provided in VCS repository for customization purposes, see section 5.1.4. Custom package names can be added to its `debian/control` file Depends: list, for example to add other Debian packages or own software possibly written in C or C++.

4.3.8 About Package Repository

The local package repository uses reprepro software [12], with additional features built on top of it. Thus basic features of reprepro apply.

Package repository is managed using command `flxrep`. The command must be run as a separate system account named flxrep. Do not use `reprepro` command directly, everything that `reprepro` can do can and should be accomplished by `flxrep` front end to `reprepro`.

Use these commands to get further information how to use `flxrep` and `reprepro`.

```
$ flxrep
$ man reprepro
```

4.3.8.1 Remove Package from Package Repository

One often encountered reprepro feature is that older packages than are already present in package repository cannot be published. If that is attempted, the packages simply are not imported. Such a situation could happen, for example, when newer version of package has been published for testing, but then one attempts to restore the older version by republishing it. To work around this the new package can be removed from the package repository before publishing the old version. Example commands to accomplish this for xr7-drivers package:

```
$ su - flxrep
$ flxrep xr7 remove rpi-testing xr7-drivers xr7-drivers-dev
$ exit
```

Note that multiple Debian packages can be generated from single source tree.

4.3.9 Increasing Disk Size

If VM disk image has been initially created too small, it can often be extended without rewriting whole images, disks or partitions.

4.3.9.1 VirtualBox

For VirtualBox VDI fixed format variant disks it is perhaps easiest to copy contents from old VDI to a new, bigger one. Example procedure:

- create a new VDI disk for the VM
- attach the new VDI to the VM still keeping the old one
- boot the VM

- partition new disk
- create filesystem on the new disk
- mount the new disk
- copy everything from old disk to the new one handling sparse files efficiently
- update UUID in `/etc/fstab`
- shutdown the VM
- detach old disk from VM
- reboot VM and verify everything works

One good way to do the copying is (as root within VM):

```
# (cd OLD-MOUNTPOINT && tar -cf - LIST-OF-DIRECTORIES-TO-COPY) |
      (cd NEW-MOUNTPOINT && tar -xSf -)
```

Another one:

```
# (cd OLD-MOUNTPOINT && cp -a --sparse=always \
LIST-OF-DIRECTORIES-TO-COPY NEW-MOUNTPOINT/.)
```

A dynamic format variant disk size could be increased with a VirtualBox command (one long line in Windows command prompt):

```
$ "%VBOX_INSTALL_PATH%\VBoxManage.exe" modifyhd
      xrs-frs-sw-environment_home.vdi --resize SIZE
```

After that the partition needs to be recreated and filesystem size increased. Because that cannot be done when filesystem is in use, it is perhaps easiest to create a temporary second VM, attach the old and new disks to it as extra disks, and to boot it from a different root filesystem disk. Then the old and new disk are available for exclusive access.

4.4 Freeing Disk Space

Command `df` can be used to check for disk usage. Example:

```
$ df -h
```

Use `du` command to see how much disk space certain directories or files consume. Examples:

```
$ du -sh $HOME/.flxbuild*
$ du -sh $HOME/*
$ du -sh $HOME
```

Building packages and SD card images may require several hundred megabytes of free disk space in order to succeed.

By default Jenkins jobs store results of all runs. As time goes by a lot of disk space may be in use for this. Often it is not necessary to keep results forever. Jenkins jobs can be configured to discard old builds.

Sometimes it is desirable to retain certain test runs forever, for example test runs of released versions. In that case it is best to move such test results away from CI server for permanent storage.

The build process uses directories in `$HOME/.flxbuild-*` as working directories. The `*` part depends on configured name in environment configuration. In some cases temporary files may accumulate in these directories, for example when the VM is shut down abruptly. Everything in these directories are recreated if necessary, but that can be a lengthy process. In any case it is always safe to delete just the temporary directories. Example:

```
$ rm -rf $HOME/.flxbuild*/tmp
```

Individual software packages are built under directory named `../build-area`, relative to the source tree (i.e. relative to the directory containing `debian` subdirectory). Over time those can accumulate and consume a substantial amount of disk space. It is safe to delete these directories. Example:

```
$ find $HOME -name build-area -type d | xargs rm –rf
```

5 XRS and FRS SW Environment Components

This section gives a depiction of the different components in the XRS SW Environment.

5.1.1 Web Server

The environment includes Nginx HTTP server [9] which is used to serve documentation, source code and Raspberry Pi SD card images that are built with the environment using CI server.

Document root of the web server on the environment file system is `/usr/share/xrs-frs-sw-env/www`. The document root has the following directory layout:

```
/usr/share/xrs-frs-sw-env/www
      ├── doc
      │     ├── XRS_FRS_Reference_Software_UG.pdf
      │     └── SpeedChip_XRS7000_Reference_Board_Manual.pdf
      ├── images
      │     └── xrs-rpi.raw.zip
      └── src
            └── xr7_drivers
```

Images is actually a symbolic link to a different location.

With the default networking setup the web server can be reached from the host using URL http://localhost/.

Note that in the default configuration there is a separate virtual host configuration for the package repository on localhost address. So within the VM the same URL accesses the package repository instead.

Nginx HTTP server configuration files are in `/etc/nginx`, note the symbolic links in `/etc/nginx/sites-enabled`. For more information on Nginx HTTP server configuration, see its documentation [9].

5.1.2 Continuous Integration Server

The environment includes Jenkins [8] as a continuous integration (CI) server. A CI server is typically used for making software compilations and builds and providing an interface to a user to trigger builds and inspect their status. A CI server typically does builds either by a predefined schedule or when required due to changes to a component that triggers a build.

With the default networking setup the CI server can be reached from the host using URL http://localhost:8080/. There is a pre-installed job for building SD card images.

For more information on Jenkins CI server configuration and usage, see its documentation [8].

5.1.3 Build Environment

The XRS and FRS SW Environment has a build environment that includes tools for

- Building Raspberry Pi SD card images
- Building FRS SoC Evaluation SD card images
- Cross-compiling software for Raspberry Pi
- Cross-compiling software for FRS Evaluation card
- Managing the version control repository
- Building software packages
- Managing the package repository

The build environment is used from command line via SSH.

For usage information about build environment, see `flxb` command online help texts.

```
$ flxb | less
```

For information on preparing own software for building and packaging, see packaging of provided source code (see section 5.1.4, and contents of `debian` subdirectory of each SW package). For packaging guidelines in general, see Debian Policy Manual [6]. For more information about commands used in `debian/rules` file, see debhelper manual pages and other debhelper documentation.

```
man debhelper
```

5.1.4 Version Control System

The environment includes a pre-installed Subversion version control system [10] repository which contains source code for certain XRS software packages and the Linux kernel. Also device tree source files are included. The software packages are built as binary packages and published to the package repository when building an SD card image.

An example layout of the `xrs` software repository could look like the following:

```
xrs
├── branches
│   ├── xr7_drivers-1.14
│   ├── xr7_drivers-1.15
│   ├── xr7-rpi-devtree-5.10
│   ├── xr7-rpi-custom-1.0
│   ├── flx-fes-lib-1.11
│   └── xr7_redundancy_supervision-1.15
└── trunk
    ├── platform-config
    ├── xr7_drivers
    ├── xr7-rpi-devtree
    ├── xr7-rpi-custom
    ├── flx-fes-lib
    ├── flx-frs-tool
    └── xr7_redundancy_supervision
```

The software packages written with a *cursive font* are not included in the environment.

`Trunk` is the location from where automated builds check out the source code for compilation and package building and publishing. In case you modify the sources, do the modifications to the code under trunk.

`Branches` is used for different versions of software packages.

The SVN repository can be accessed in the VM using URL `svn+ssh://localhost/home/svn/src`. The same URL can be used on the host, too, if port forwarding for SSH port has been configured as described in section 3.3.2.4.

For more information on Subversion usage, see Version Control with Subversion [11].

5.1.5 Package Repository

The environment includes a Debian package repository with pre-published binary packages to build a Raspberry Pi SD card image for XRS. The repository is not a full mirror of the Debian repository, but internet connectivity is required to access the official Debian repositories [4]. The environment uses apt-cacher-ng as an APT proxy to reduce download traffic from Debian servers.

When a software package is built to a binary package, it is published to the package repository. When SD card images are built, binary packages are installed from the repository.

Certain XRS software packages are included in the image as source code and are thus available for modifications. When an image is built, these software packages are compiled and built as binary packages which are published to the package repository before being used in the image building process.

The local package repository uses reprepro software [12], with additional features built on top of it. For more information on package archive management, see reprepro documentation [12] and flxrep command help texts (run it as user flxrep without any parameters). Reprepro manual page contains also a lot of useful information.

```
$ flxrep
$ man reprepro
```

6 Abbreviations

Term	Description
AHCI	Advanced Host Controller Interface
BIOS	Basic Input/Output System
CI	Continuous Integration
DNS	Domain Name System
EEPROM	Electrically Erasable Programmable Read-Only Memory
GMII	Gigabit Media-Independent Interface
GPT	GUID Partition Table
GPU	Graphics Processing Unit
GUI	Graphical User Interface
GUID	Globally Unique Identifer
HSR	High-availability Seamless Redundancy
HTTP	Hypertext Transfer Protocol
I^2C	Inter-Integrated Circuit
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
MAC	Media Access Control
MBR	Master Boot Record
MDIO	Management Data Input/Output
MII	Media-Independent Interface
NAT	Network Address Translation
NTP	Network Time Protocol
OS	Operating System
PC	Personal Computer
PRP	Parallel Redundancy Protocol
PTP	Precision Time Protocol
RGMII	Reduced Gigabit Media-Independent Interface
RPi	Raspberry Pi
SATA	Serial ATA
SFP	Small Form-factor Pluggable Transceiver
SGMII	Serial Gigabit Media-Independent Interface
SSH	Secure Shell
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
URL	Uniform Resource Locator
VCS	Version Control System
VDI	Virtual Disk Image
VM	Virtual Machine

7 References

[1] SpeedChip XRS7000 and XRS3000 User Manual, http://www.flexibilis.com/products/downloads/

[2] SpeedChip XRS7000 Reference Board User Manual, http://www.flexibilis.com/products/downloads/

[3] Debian GNU/Linux distribution, https://www.debian.org/

[4] Debian repository mirrors, https://www.debian.org/mirror/list

[5] Debian Users' Manuals, https://www.debian.org/doc/user-manuals

[6] Debian Policy Manual, httsp://www.debian.org/doc/debian-policy/

[7] Oracle VirtualBox, https://www.virtualbox.org/

[8] Jenkins Continuous Integration Server, https://www.jenkins.io/

[9] Nginx HTTP server, https://nginx.org/

[10] Subversion Version Control System, https://subversion.apache.org/

[11] Version Control with Subversion, http://svnbook.red-bean.com/

[12] Reprepro, http://mirrorer.alioth.debian.org/

[13] Network Configuration Protocol, RFC 4741, https://tools.ietf.org/html/rfc4741

[14] Using the NETCONF Configuration Protocol over Secure SHell (SSH), RFC 4742, http://tools.ietf.org/html/rfc4742

[15] Oracle VirtualBox end-user documentation, https://www.virtualbox.org/wiki/End-user_documentation

[16] GNU GRUB, https://www.gnu.org/software/grub/

[17] XR7 PTP Design Specification, xr7_ptp_design.pdf

[18] XR7 Redundancy Supervision Design Specification, xr7_redundancy_supervision_design.pdf

[19] FRS SoC Evaluation Design Specification, FRS_SoC_evaluation_design.pdf