OpenCPI
FSK App Guide
(E310 Supplement)

Version 1.5

Revision History

Revision	Description of Change	Date
v1.3.1-E3XX	Updated for E310 support	3/2018
v1.4	Updated with simplications and references to assets' document	9/2018
v1.5	Version bump only	4/2019

Table of Contents

1 Document Scope

This document describes the OpenCPI FSK demo application. It includes a description of the application, instructions to setup the hardware, build of bitstreams, and execution of the application itself on various platforms.

2 Description

For more information on this application, see `ocpi.assets`'s more in-depth version of the *FSK_app* document.

3 Hardware Portability

This application is specific to the `e3xx` platform.

4 Building the Application

4.1 Dependencies

The tables below breakdown the workers used within the various platforms and modes of the FSK App. Appendix A shows the exact worker configurations used in the HDL assemblies. See the individual component data sheets for more information and build instructions. Similarly, the HDL platform worker and configurations for the intended radio must be compiled prior to building the various FSK bitstreams.

4.2 FSK Mode Configurations

4.2.1 Common to all Hardware

Application XML	filerw	rx	tx	txrx	bbloopback
app_fsk_filerw (dependency only, no build required)	x				
HDL Assemblies	filerw	rx	tx	txrx	bbloopback
fsk_filerw	x				
dc_offset_iq_imbalance_mixer_cic_dec_rp_cordic_fir_real		x			
mfsk2_zp16_fir_real_phase_to_amp_cordic_cic_int			x		
fsk_modem				x	x
RX Path Workers	filerw	rx	tx	txrx	bbloopback
dc_offset_filter.hdl		x		x	x
iq_imbalance_fixer.hdl		x		x	x
complex_mixer.hdl	x	x		x	x
cic_dec.hdl	x	x		x	x
rp_cordic.hdl	x	x		x	x
fir_real_sse.hdl	x	x		x	x
baudTracking.rcc	x	x		x	x
real_digitizer.rcc	x	x		x	x
file_write.rcc	x	x		x	x
TX Path Workers	filerw	rx	tx	txrx	bbloopback
file_read.rcc	x		x	x	x
mfsk_mapper.hdl	x		x	x	x
zero_pad.hdl	x		x	x	x
fir_real_sse.hdl	x		x	x	x
phase_to_amp_cordic.hdl	x		x	x	x
cic_int.hdl	x		x	x	x

4.2.2 Additional Dependencies for Ettus E310

Application XML	filerw	rx	tx	txrx	bbloopback
app_fsk_rx_e3xx (dependency only, no build required)		x			
app_fsk_tx_e3xx (dependency only, no build required)			x		
app_fsk_txrx_e3xx (dependency only, no build required)				x	
RX or TX Path Workers	filerw	rx	tx	txrx	bbloopback
ad9361_data_sub.hdl		x	x	x	
RX Path Workers	filerw	rx	tx	txrx	bbloopback
ad9361_adc.hdl		x		x	
ad9361_adc_sub.hdl		x		x	
TX Path Workers	filerw	rx	tx	txrx	bbloopback
ad9361_dac.hdl			x	x	
ad9361_dac_sub.hdl			x	x	
Endpoint Proxies	filerw	rx	tx	txrx	bbloopback
e3xx_rx.rcc		x		x	
e3xx_tx.rcc			x	x	
SPI Command and Control	filerw	rx	tx	txrx	bbloopback
ad9361_config.hdl		x	x	x	
ad9361_config_proxy.rcc		x	x	x	
ad9361_spi.hdl		x	x	x	
e3xx_mimo_xcvr_ad5662.hdl		x	x	x	
I2C Command and Control	filerw	rx	tx	txrx	bbloopback
e3xx_i2c.hdl		x	x	x	
Analog Filter Control	filerw	rx	tx	txrx	bbloopback
e3xx_mimo_xcvr_filter.hdl		x	x	x	
e3xx_mimo_xcvr_filter_proxy.rcc		x	x	x	

4.3 HDL Assembly and HDL Container

For more information on this application, see `ocpi.assets`'s more in-depth version of the *FSK_app* document.

4.4 Performance and Resource Utilization

4.4.1 filerw

For more information on this application, see `ocpi.assets`'s more in-depth version of the *FSK_app* document.

4.4.2 tx

Table 1: Resource Utilization Table for hdl-assembly "mfsk2_zp16_fir_real_phase_to_amp_cordic_cic_int"

Container	OCPI Platform	OCPI Target	Tool	Version	Device	Registers (Typ)	LUTs (Typ)	Fmax (MHz) (Typ)	Memory/Special Functions
base	e3xx	zynq	Vivado	2017.1	xc7z020clg484-1	15764	12512	100.0	DSP48E1: 66 BUFGCTRL: 1 BUFG: 1 RAMB36E1: 34
cnt_0rx_1tx_thruasm_mode_2_cmos_e3xx	e3xx	zynq	Vivado	2017.1	xc7z020clg484-1	15764	12512	100.0	DSP48E1: 66 BUFGCTRL: 1 BUFG: 1 RAMB36E1: 34

4.4.3 rx

Table 2: Resource Utilization Table for hdl-assembly "dc_offset_iq_imbalance_mixer_cic_dec_rp_cordic_fir_real"

Container	OCPI Platform	OCPI Target	Tool	Version	Device	Registers (Typ)	LUTs (Typ)	Fmax (MHz) (Typ)	Memory/Special Functions
cnt_1rx_0tx_thruasm_mode_2_cmos_e3xx	e3xx	zynq	Vivado	2017.1	xc7z020clg484-1	16969	16107	100.0	DSP48E1: 82 ODDR: 1 BUFGCTRL: 2 BUFG: 2 RAMB36E1: 18 RAMB18E1: 1

4.4.4 txrx/bbloopback

Table 3: Resource Utilization Table for hdl-assembly "fsk_modem"

Container	OCPI Platform	OCPI Target	Tool	Version	Device	Registers (Typ)	LUTs (Typ)	Fmax (MHz) (Typ)	Memory/Special Functions
cnt_1rx_1tx_thruasm_mode_2_cmos_e3xx	e3xx	zynq	Vivado	2017.1	xc7z020clg484-1	28514	25366	100.0	DSP48E1: 148 ODDR: 8 BUFGCTRL: 2 BUFG: 2 RAMB36E1: 34 RAMB18E1: 2

4.5 Executable

To build for the Ettus E310 (which runs the xilinx13_4 PetaLinux operating system), run the following command from the FSK directory:

```
ocpidev build --rcc-platform xilinx13_4
```

For more information on this application, see `ocpi.assets`'s more in-depth version of the *FSK_app* document.

5 Testing the Application

For more information on this application, see `ocpi.assets`'s more in-depth version of the *FSK_app* document.

5.1 make show

In order to test the application using the various modes mentioned above, `make show` can be run from the `applications/FSK` directory. This provides instructions (for Zynq-Based Platforms) for setting `OCPI_LIBRARY_PATH` on the hardware platform and then running the application. Finally, it explains how to verify the output data on the development computer. The following sections provide further insight into these instructions.

5.2 Artifacts

For more information on this application, see `ocpi.assets`'s more in-depth version of the *FSK_app* document. Appendix B includes a list of the artifacts required for each platform and mode.

5.3 Arguments to executable

For more information on this application, see `ocpi.assets`'s more in-depth version of the *FSK_app* document. Example arguments for the **Ettus E310 BSP** using the SMA ports RX=RX2A TX=TRXA:

Parameter	Value
RF frontend	(not set / default)
Runtime (s)	20
RX SMA channel	RX2A
TX SMA channel	TRXA
rx_sample_rate	4
rx_rf_center_freq	2400
rx_rf_bw	-1 (default)
rx_rf_gain	12
rx_bb_bw	4
rx_bb_gain	-1 (default)
rx_if_center_freq	0
tx_sample_rate	4
tx_rf_center_freq	2400
tx_rf_bw	-1 (default)
tx_rf_gain	-28
tx_bb_bw	4
tx_bb_gain	-1 (default)

Note that if the application complains about the output file or directory, run '`mkdir odata`' in the FSK directory and rerun the executable.

5.4 Library Path Requirements

Prior to running the application, the environment variable OCPI_LIBRARY_PATH must be configure, such that, all of the FSK application's run-time artifacts can be located. OpenCPI conveniently provides access to a project's run-time artifacts at the top-level of each project in a directory called artifacts. Reference the OpenCPI Application Development Guide for more about OCPI_LIBRARY_PATH.

Examples of library paths that could be used can be seen below:

The following are recommendations for configuring the OCPI_LIBRARY_PATH based on the platform, the use of a daughter card and specific slot that card is installed. For all recommendations:

- All paths are relative to the applications/rx_app/ directory.

Recommended Library Path
Follow the instructions contained in the FSK application's Makefile. They can be viewed by opening the Makefile in an editor, or by executing "make show" from within the assets/applications/FSK/.

5.5 Expected results

In the case of the *filerw*, *rx*, *txrx*, and *bbloopback* modes, assuming transmission of the idata/Os.jpeg input file, the expected result is a transmitted copy of the JPEG file. A Linux program such as Eye of GNOME (eog) may be used to display the JPEG file. The file is shown in Figure 1.

In the case of the *tx* mode, verification is obtained by viewing the RF spectrum on a spectrum analyzer. An example of the transmitted spectrum may be seen in Figure 2.

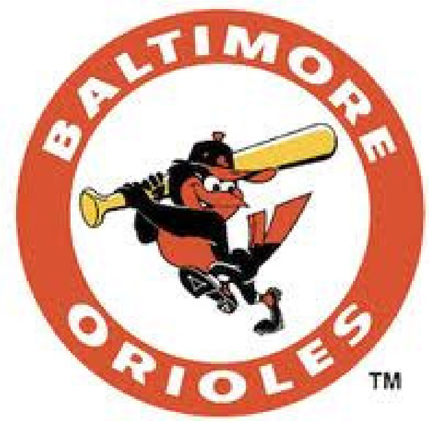
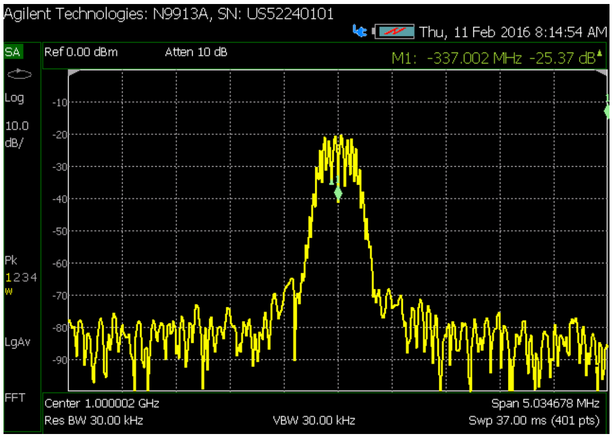


Figure 1: FSK input file


Agilent Technologies: N9913A, SN: US52240101

Thu, 11 Feb 2016 8:14:54 AM

Ref 0.00 dBm Atten 10 dB

M1: -337.002 MHz -25.37 dB

Log 10.0 dB/

Pk 1234 W

LgAv

FFT

Center 1.000002 GHz Span 5.034678 MHz

Res BW 30.00 kHz VBW 30.00 kHz Swp 37.00 ms (401 pts)

Figure 2: Output of FSK App RF transmit

5.6 Known Issues

- The *rx* and *tx* modes suffer from limited carrier recovery ability. The requested center frequency may need to be adjusted to a value other than the exact expected nominal value.
- Sometimes the radio can get into an unwanted state. If unusual results are seen, run `ocpihdl unload` and rerun the application.

6 Appendix A: Worker Parameters

Configuration information for each component in the application can be found in the application XML for that configuration. *E.g.* for the Ettus E310 in txrx mode, `app_fsk_txrx_e3xx`. Further information can be determined by browsing the chosen platform configurations and container XMLs for the given configuration and platform.

7 Appendix B: Artifacts

Each worker that is required for a given configuration of this application has an artifact that must be found at runtime (located via one of the `OCPI_LIBRARAY_PATH` choices listed above). Reference the lists of workers for each configuration and platform to determine the artifacts required. Each required RCC worker corresponds to a required `target-<shortened-rcc-platform>/<worker>_s.so` artifact. All required HDL workers (together) correspond to a single required `<assembly>_<platform>_<platform-config>_<container>.bitz` artifact.

7.1 Ettus E310

filerw

- fsk_filerw_e3xx_base.bitz
- target-xilinx13_4/file_read_s.so
- target-xilinx13_4/Baudtracking_simple_s.so
- target-xilinx13_4/real_digitizer_s.so
- target-xilinx13_4/file_write_s.so

rx

- dc_offset_iq_imbalance_mixer_cic_dec_rp_cordic_fir_real_e3xx_cfg_1rx_0tx_mode_2_cmos_cnt_1rx_0tx_mode_2_bypassasm_e3xx_mimo_xcvr_CMOS_e3xx.bitz

- target-xilinx13_4/Baudtracking_simple_s.so
- target-xilinx13_4/real_digitizer_s.so
- target-xilinx13_4/file_write_s.so
- target-xilinx13_4/ad9361_config_proxy_s.so
- target-xilinx13_4/e3xx_mimo_xcvr_filter_proxy_s.so
- target-xilinx13_4/e3xx_rx_s.so

tx

- mfsk2_zp16_fir_real_phase_to_amp_cordic_cic_int_e3xx_cfg_0rx_1tx_mode_2_cmos_cnt_0rx_1tx_mode_2_thruasm_e3xx_mimo_xcvr_CMOS_e3xx.bitz

- target-xilinx13_4/file_read_s.so
- target-xilinx13_4/ad9361_config_proxy_s.so
- target-xilinx13_4/e3xx_mimo_xcvr_filter_proxy_s.so
- target-xilinx13_4/e3xx_tx_s.so

txrx/bbloopback

- fsk_modem_e3xx_cfg_1rx_1tx_mode_2_cmos_cnt_1rx_1tx_mode_2_thruasm_e3xx_mimo_xcvr_CMOS_e3xx.bitz

- target-xilinx13_4/file_read_s.so
- target-xilinx13_4/Baudtracking_simple_s.so
- target-xilinx13_4/real_digitizer_s.so
- target-xilinx13_4/file_write_s.so
- target-xilinx13_4/ad9361_config_proxy_s.so
- target-xilinx13_4/e3xx_mimo_xcvr_filter_proxy_s.so
- target-xilinx13_4/e3xx_rx_s.so
- target-xilinx13_4/e3xx_tx_s.so