OpenCPI
FSK App Guide

Version 1.5

Revision History

Revision	Description of Change	Date
v1.1	Initial Release	3/2017
v1.2	Updated for OpenCPI Release 1.2	8/2017
v1.3	Updated for OpenCPI Release 1.3	1/2018
v1.3.1	Updated for OpenCPI Release 1.3.1, including FMCOMMS2/3 support	3/2018
v1.4	Updated recommendations for configuring OCPI_LIBRARY_PATH	9/2018
v1.5	Deprecated Zipper; Moved to Appendix	3/2019

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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 Supported Hardware Setups

This app is supported on the following hardware configurations:

- Zedboard/FMCOMMS2
- Zedboard/FMCOMMS3
- x86/ML605/FMCOMMS2 in FMC LPC slot
- x86/ML605/FMCOMMS3 in FMC LPC slot
- Matchstiq-Z1

3 Description

The FSK App may be run in one of five available modes. The modes are *filerw*, *rx*, *tx*, *txrx*, and *bbloopback*. The *filerw* mode uses file_read and file_write workers to process the input using only application workers (platform agnostic) in a purely digital fashion. A block diagram of the FSK App *filerw* mode can be seen in Figure 1.

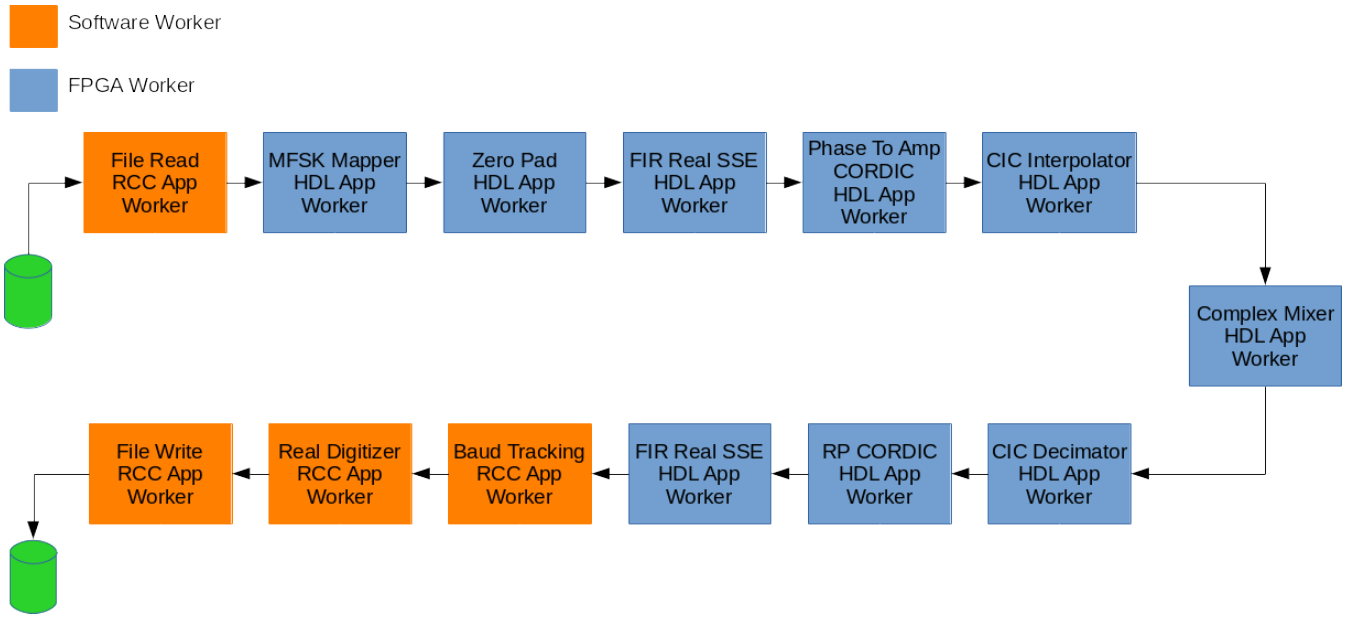

Figure 1: FSK App *filerw* mode Block Diagram

The *rx* mode inputs IQ data from the Lime ADC and processes the FSK signal down to bits that are written to file. A block diagram of the FSK App *rx* mode can be seen in Figure 2.

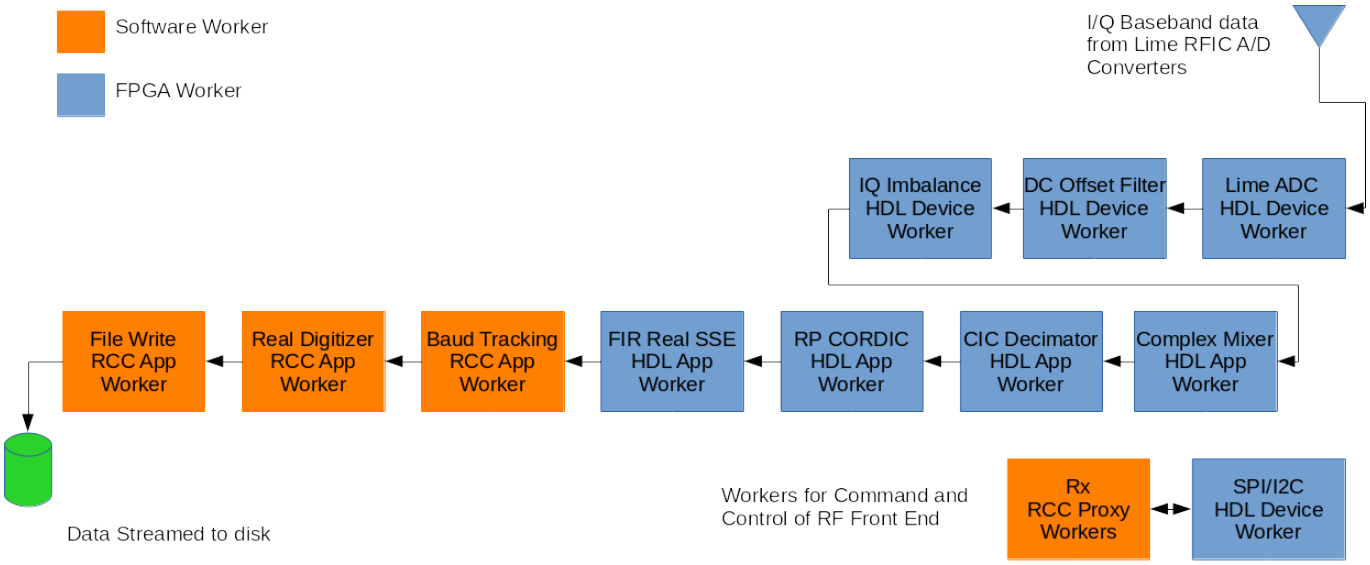

Figure 2: FSK App *rx* mode Block Diagram

The *tx* mode inputs a file from disk, modulates the input as a FSK signal, and transmits the input via the Lime DAC. A block diagram of the FSK App *tx* mode can be seen in Figure 3.

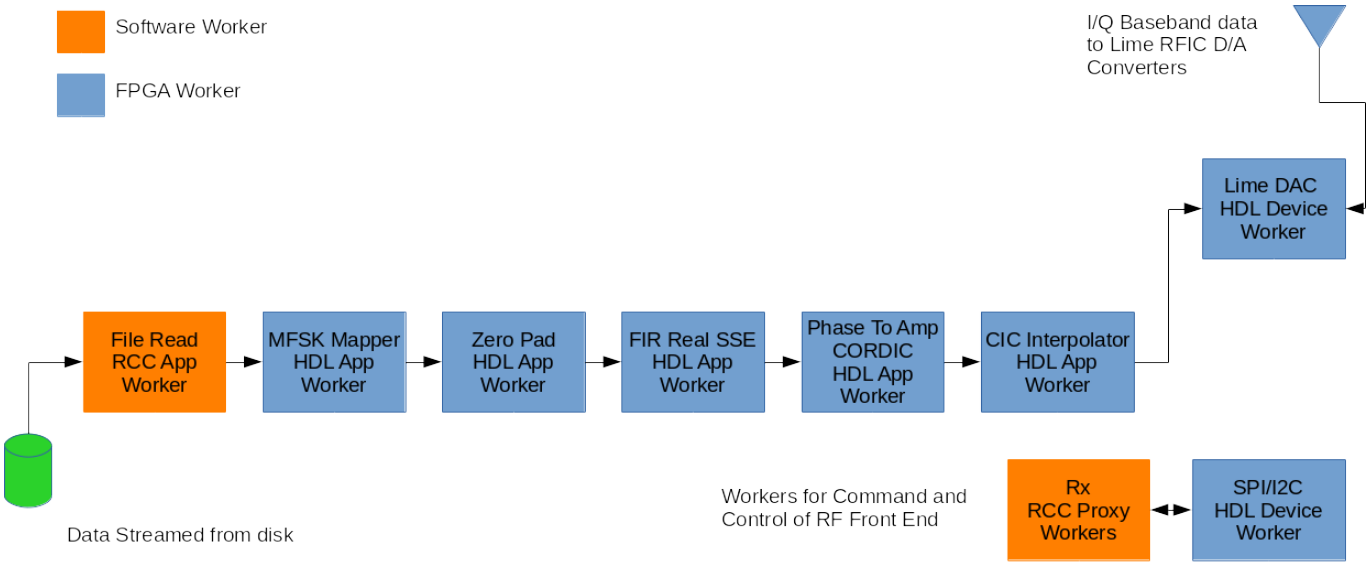

Figure 3: FSK App *tx* mode Block Diagram

The *txrx* mode is the full transceiver mode of the application which combines the functionality of Figures 2 and 3 into a single application. This mode transmits input file data as the radio RF TX output and inputs RF RX radio input that is written to file. The *bbloopback* mode utilizes the same HDL assembly and application XML as the *txrx* mode but utilizes a built-in test mode of the Lime transceiver to loopback analog data at baseband.

The *tx*, *txrx*, and *bbloopback* modes for the Matchstiq-Z1 contain the matchstiq_z1_gp_out device worker which can control the three GPIO pins present on the Matchstiq-Z1. The application XMLs give an example of how to use the device worker.

3.1 Application Specifications

3.1.1 Baud Rate

The baud rate for the application is based on the following properties:

- ADC/DAC Sample Rate (S)
- CIC Decimation/Interpolation Factor (R)
- Number of zeros inserted between symbols (Z)

It can be computed using the following equation:

$$Baud\ Rate = S\ /\ R\ /\ (Z+1) \tag{1}$$

Using the default settings for the Ettus E310 platform, the resulting baud rate is approximately 6.4K baud.

$$Baud\ Rate = S\ /\ R\ /\ (Z+1) = 4e6\ /\ 16\ /\ (38+1)\ =\ 6410 \tag{2}$$

3.1.2 Frequency Deviation

The frequency deviation for the application is based on the following characteristics of the application:

- Pulse shaping FIR output amplitude (fir_output)
- Width of data (DATA_WIDTH)
- CIC Decimation/Interpolation Factor (R)
- ADC/DAC Sample Rate (S)

After the bits of the input file are mapped to symbols, zeros are inserted in between symbols. After zero padding, the output is pulse shaped by a root raised cosine FIR filter. The taps of the filter are configurable and should be based on the expected baud rate of the application. See `applications/FSK/scripts/gen_rrcos_taps.py` for more information. Using the default tap values, the output of the filter ranges from approximately +3300 to -3300. These output values from the FIR determine the min and max frequencies produced by the phase_to_amp_cordic according to the following equation.

$$cordic\_freq = \frac{fir\_output}{2^{DATA\_WIDTH}} = \frac{+/-3300}{2^{16}} = +/-0.0504\ cycles\ per\ sample \tag{3}$$

The output of the CORDIC is upsampled by a interpolating CIC filter. The output data of the CIC is passed to the DAC, which has a configurable sample rate. The resulting output frequency of the DAC is defined by:

$$output\_freq = cordic\_freq\ /\ R\ *\ S \tag{4}$$

Using the default settings for the Ettus E310 platform, the resulting frequency deviation is approximately 12588 Hz with mark and space frequencies at 2400012588 Hz and 2399987411 Hz.

$$output\_freq = cordic\_freq\ /\ R\ *\ S = 0.717\ /\ 16\ *\ 4e6\ =\ 12588\ Hz \tag{5}$$

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 FMCOMMS2

Application XML	filerw	rx	tx	txrx	bbloopback
app_fsk_rx_fmcomms2 (dependency only, no build required)		x			
app_fsk_tx_fmcomms2 (dependency only, no build required)			x		
app_fsk_txrx_fmcomms2 (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
fmcomms_2_3_rx.rcc		x		x	
fmcomms_2_3_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	
I2C Command and Control	filerw	rx	tx	txrx	bbloopback
fmcomms_2_3_i2c.hdl		x	x	x	

4.2.3 Additional Dependencies for FMCOMMS3

Application XML	filerw	rx	tx	txrx	bbloopback
app_fsk_rx_fmcomms3 (dependency only, no build required)		x			
app_fsk_tx_fmcomms3 (dependency only, no build required)			x		
app_fsk_txrx_fmcomms3 (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
fmcomms_2_3_rx.rcc		x		x	
fmcomms_2_3_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	
I2C Command and Control	filerw	rx	tx	txrx	bbloopback
fmcomms_2_3_i2c.hdl		x	x	x	

4.2.4 Additional Dependencies for Matchstiq-Z1

Application XML	filerw	rx	tx	txrx	bbloopback
app_fsk_rx_matchstiq_z1 (dependency only, no build required)		x			
app_fsk_tx_matchstiq_z1 (dependency only, no build required)			x		
app_fsk_txrx_matchstiq_z1 (dependency only, no build required)				x	x
RX Path Workers	filerw	rx	tx	txrx	bbloopback
lime_adc.hdl		x		x	x
TX Path Workers	filerw	rx	tx	txrx	bbloopback
lime_dac.hdl			x	x	x
Endpoint Proxies	filerw	rx	tx	txrx	bbloopback
matchstiq_z1_rx.rcc		x		x	x
matchstiq_z1_tx.rcc			x	x	x
SPI Command and Control	filerw	rx	tx	txrx	bbloopback
lime_rx_proxy.rcc		x		x	x
lime_rx.hdl		x		x	x
lime_tx_proxy.rcc			x	x	x
lime_tx.hdl			x	x	x
lime_spi.hdl		x	x	x	x
I2C Command and Control	filerw	rx	tx	txrx	bbloopback
si5338_proxy.rcc		x	x	x	x
si5338.hdl		x	x	x	x
matchstiq_z1_avr_proxy.rcc		x	x	x	x
matchstiq_z1_avr.hdl		x	x	x	x
tmp100_proxy.rcc		x	x	x	x
tmp100.hdl		x	x	x	x
matchstiq_z1_pca9535_proxy.rcc		x	x	x	x
pca9535.hdl		x	x	x	x
matchstiq_z1_i2c.hdl		x	x	x	x

4.3 Performance and Resource Utilization

4.3.1 filerw

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

Container	OCPI Platform	OCPI Target	Tool	Version	Device	Registers (Typ)	LUTs (Typ)	Fmax (MHz) (Typ)	Memory/Special Functions
base	alst4	stratix4	Quartus	17.1.0	EP4SGX230KF40C2	73626	52082	N/A	DSP18: 284 GXB Receiver PCS: 4 GXB Transmitter PCS: 4 GXB Transmitter PMA: 4 PLL: 1 Block Memory Bits: 761972 GXB Receiver PMA: 4
base	zed	zynq	Vivado	2017.1	xc7z020clg484-1	25056	21862	100.0	BUFGCTRL: 1 BUFG: 1 RAMB36E1: 34 DSP48E1: 139
base	ml605	virtex6	ISE	14.7	6vlx240tff1156-1	30637	41283	125.109	BUFGCTRL: 5 BUFG: 5 DSP48E1: 144
base	zed_ise	zynq_ise	ISE	14.7	7z020clg484-1	20398	27189	100.341	BUFGCTRL: 1 BUFG: 1 DSP48E1: 144
base	matchstiq_z1	zynq	Vivado	2017.1	xc7z020clg484-1	25419	22065	100.0	BUFGCTRL: 1 BUFG: 1 RAMB36E1: 34 DSP48E1: 139

4.3.2 tx

Table 2: 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	zed_ise	zynq_ise	ISE	14.7	7z020clg484-1	11791	15582	100.02	BUFGCTRL: 1 BUFG: 1 DSP48E1: 68
base	alst4	stratix4	Quartus	17.1.0	EP4SGX230KF40C2	63957	40886	N/A	DSP18: 136 GXB Receiver PCS: 4 GXB Transmitter PCS: 4 GXB Transmitter PMA: 4 PLL: 1 Block Memory Bits: 761972 GXB Receiver PMA: 4
base	ml605	virtex6	ISE	14.7	6vlx240tff1156-1	21962	29689	113.43	BUFGCTRL: 5 BUFG: 5 DSP48E1: 68
base	matchstiq_z1	zynq	Vivado	2017.1	xc7z020clg484-1	15763	12510	100.0	BUFGCTRL: 1 BUFG: 1 RAMB36E1: 34 DSP48E1: 66
base	zed	zynq	Vivado	2017.1	xc7z020clg484-1	15400	12297	100.0	BUFGCTRL: 1 BUFG: 1 RAMB36E1: 34 DSP48E1: 66
cnt_0rx_1tx_thruasm_fmcomms_2_3_lpc_LVDS_ml605	ml605	virtex6	ISE	14.7	6vlx240tff1156-1	21962	29689	113.43	BUFGCTRL: 5 BUFG: 5 DSP48E1: 68
cnt_0rx_1tx_thruasm_fmcomms_2_3_lpc_LVDS_zed	zed	zynq	Vivado	2017.1	xc7z020clg484-1	15400	12297	100.0	BUFGCTRL: 1 BUFG: 1 RAMB36E1: 34 DSP48E1: 66
cnt_0rx_1tx_thruasm_fmcomms_2_3_lpc_LVDS_zed	zed_ise	zynq_ise	ISE	14.7	7z020clg484-1	11791	15582	100.02	BUFGCTRL: 1 BUFG: 1 DSP48E1: 68
cnt_0rx_1tx_thruasm_matchstiq_z1	matchstiq_z1	zynq	Vivado	2017.1	xc7z020clg484-1	15763	12510	100.0	BUFGCTRL: 1 BUFG: 1 RAMB36E1: 34 DSP48E1: 66
cnt_0rx_1tx_thruasm_zipper_hpc_ml605	ml605	virtex6	ISE	14.7	6vlx240tff1156-1	21962	29689	113.43	BUFGCTRL: 5 BUFG: 5 DSP48E1: 68

cnt_0rx_1tx_thruasm_zipper_hsmc_a_alst4	alst4	stratix4	Quartus	17.1.0	EP4SGX230KF40C2	63957	40886	N/A	DSP18: 136 GXB Receiver PCS: 4 GXB Transmitter PCS: 4 GXB Transmitter PMA: 4 PLL: 1 Block Memory Bits: 761972 GXB Receiver PMA: 4
cnt_0rx_1tx_thruasm_zipper_hsmc_b_alst4	alst4	stratix4	Quartus	17.1.0	EP4SGX230KF40C2	63957	40886	N/A	DSP18: 136 GXB Receiver PCS: 4 GXB Transmitter PCS: 4 GXB Transmitter PMA: 4 PLL: 1 Block Memory Bits: 761972 GXB Receiver PMA: 4
cnt_0rx_1tx_thruasm_zipper_lpc_ml605	ml605	virtex6	ISE	14.7	6vlx240tff1156-1	21962	29689	113.43	BUFGCTRL: 5 BUFG: 5 DSP48E1: 68
cnt_0rx_1tx_thruasm_zipper_lpc_zed	zed	zynq	Vivado	2017.1	xc7z020clg484-1	15400	12297	100.0	BUFGCTRL: 1 BUFG: 1 RAMB36E1: 34 DSP48E1: 66
cnt_0rx_1tx_thruasm_zipper_lpc_zed	zed_ise	zynq_ise	ISE	14.7	7z020clg484-1	11791	15582	100.02	BUFGCTRL: 1 BUFG: 1 DSP48E1: 68

4.3.3 rx

Table 3: 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_fmcomms_2_3_hpc_LVDS_ml605	ml605	virtex6	ISE	14.7	6vlx240tff1156-1	20103	26600	125.141	BUFGCTRL: 6 BUFG: 6 DSP48E1: 85
cnt_1rx_0tx_thruasm_fmcomms_2_3_lpc_LVDS_ml605	ml605	virtex6	ISE	14.7	6vlx240tff1156-1	20103	26600	125.141	BUFGCTRL: 6 BUFG: 6 DSP48E1: 85
cnt_1rx_0tx_thruasm_fmcomms_2_3_lpc_LVDS_zed	zed	zynq	Vivado	2017.1	xc7z020clg484-1	16104	15576	100.0	BUFGCTRL: 2 BUFG: 2 RAMB36E1: 21 DSP48E1: 82
cnt_1rx_0tx_thruasm_fmcomms_2_3_lpc_LVDS_zed	zed_ise	zynq_ise	ISE	14.7	7z020clg484-1	13753	18714	100.14	BUFGCTRL: 2 BUFG: 2 DSP48E1: 85
cnt_1rx_0tx_thruasm_matchstiq_z1	matchstiq_z1	zynq	Vivado	2017.1	xc7z020clg484-1	17159	16683	100.0	BUFGCTRL: 2 BUFG: 2 RAMB36E1: 21 DSP48E1: 82 RAMB18E1: 2
cnt_1rx_0tx_thruasm_zipper_hpc_ml605	ml605	virtex6	ISE	14.7	6vlx240tff1156-1	20103	26600	125.141	BUFGCTRL: 6 BUFG: 6 DSP48E1: 85
cnt_1rx_0tx_thruasm_zipper_hsmc_a_alst4	alst4	stratix4	Quartus	17.1.0	EP4SGX230KF40C2	48360	35157	N/A	DSP18: 166 GXB Receiver PCS: 4 GXB Transmitter PCS: 4 GXB Transmitter PMA: 4 PLL: 1 Block Memory Bits: 498916 GXB Receiver PMA: 4
cnt_1rx_0tx_thruasm_zipper_hsmc_b_alst4	alst4	stratix4	Quartus	17.1.0	EP4SGX230KF40C2	48360	35157	N/A	DSP18: 166 GXB Receiver PCS: 4 GXB Transmitter PCS: 4 GXB Transmitter PMA: 4 PLL: 1 Block Memory Bits: 498916 GXB Receiver PMA: 4
cnt_1rx_0tx_thruasm_zipper_lpc_ml605	ml605	virtex6	ISE	14.7	6vlx240tff1156-1	20103	26600	125.141	BUFGCTRL: 6 BUFG: 6 DSP48E1: 85
cnt_1rx_0tx_thruasm_zipper_lpc_zed	zed	zynq	Vivado	2017.1	xc7z020clg484-1	16104	15576	100.0	BUFGCTRL: 2 BUFG: 2 RAMB36E1: 21 DSP48E1: 82
cnt_1rx_0tx_thruasm_zipper_lpc_zed	zed_ise	zynq_ise	ISE	14.7	7z020clg484-1	13753	18714	100.14	BUFGCTRL: 2 BUFG: 2 DSP48E1: 85

4.3.4 txrx/bbloopback

Table 4: 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_fmcomms_2_3_lpc_LVDS_ml605	ml605	virtex6	ISE	14.7	6vlx240tff1156-1	33342	45170	115.194	BUFGCTRL: 7 BUFG: 7 DSP48E1: 153
cnt_1rx_1tx_thruasm_fmcomms_2_3_lpc_LVDS_zed	zed_ise	zynq_ise	ISE	14.7	7z020clg484-1	23062	30909	100.2	BUFGCTRL: 3 BUFG: 3 DSP48E1: 153
cnt_1rx_1tx_thruasm_fmcomms_2_3_lpc_LVDS_zed	zed	zynq	Vivado	2017.1	xc7z020clg484-1	27735	24928	100.0	BUFGCTRL: 3 BUFG: 3 RAMB36E1: 37 DSP48E1: 148 RAMB18E1: 1
cnt_1rx_1tx_thruasm_matchstiq_z1	matchstiq_z1	zynq	Vivado	2017.1	xc7z020clg484-1	31628	27850	100.0	BUFGCTRL: 3 BUFG: 3 RAMB36E1: 53 DSP48E1: 148 RAMB18E1: 3
cnt_1rx_1tx_thruasm_zipper_hpc_ml605	ml605	virtex6	ISE	14.7	6vlx240tff1156-1	33342	45170	115.194	BUFGCTRL: 7 BUFG: 7 DSP48E1: 153
cnt_1rx_1tx_thruasm_zipper_hsmc_a_alst4	alst4	stratix4	Quartus	17.1.0	EP4SGX230KF40C2	76579	55909	N/A	DSP18: 302 GXB Receiver PCS: 4 GXB Transmitter PCS: 4 GXB Transmitter PMA: 4 PLL: 1 Block Memory Bits: 861812 GXB Receiver PMA: 4
cnt_1rx_1tx_thruasm_zipper_hsmc_b_alst4	alst4	stratix4	Quartus	17.1.0	EP4SGX230KF40C2	76579	55909	N/A	DSP18: 302 GXB Receiver PCS: 4 GXB Transmitter PCS: 4 GXB Transmitter PMA: 4 PLL: 1 Block Memory Bits: 861812 GXB Receiver PMA: 4
cnt_1rx_1tx_thruasm_zipper_lpc_ml605	ml605	virtex6	ISE	14.7	6vlx240tff1156-1	33342	45170	115.194	BUFGCTRL: 7 BUFG: 7 DSP48E1: 153
cnt_1rx_1tx_thruasm_zipper_lpc_zed	zed_ise	zynq_ise	ISE	14.7	7z020clg484-1	23062	30909	100.2	BUFGCTRL: 3 BUFG: 3 DSP48E1: 153
cnt_1rx_1tx_thruasm_zipper_lpc_zed	zed	zynq	Vivado	2017.1	xc7z020clg484-1	27735	24928	100.0	BUFGCTRL: 3 BUFG: 3 RAMB36E1: 37 DSP48E1: 148 RAMB18E1: 1

4.4 Executable

The software portion of the application consists of a C++ program written using the OpenCPI C++ API as well as RCC proxy workers for command and control functionality. The program references the appropriate application XML file for the requested hardware and mode. The app XML files contain all of the property settings for the components in each application, except for the configuration of the endpoint proxy(ies). These endpoint proxy-related settings are passed via command-line prompted values to the appropriate endpoint proxy workers.
To build for the host platform (which is the case if ML605 or Stratix IV platform is intended to be used), run the following commands from the FSK directory:

```
ocpidev build
```

To build for the Zedboard or Matchstiq-Z1 (which run the xilinx13_3 PetaLinux operating system), run the following command from the FSK directory:

```
ocpidev build --rcc-platform xilinx13_3
```

5 Testing the Application

5.1 Baud Synchronization

The input filename for the application is idata/Os.jpeg. It is modified from an original JPEG image (see Figure 4) with data prepended to it for baud synchronization purposes (240 bytes of an alternating 1-0 pattern followed by 2 bytes are the value 0xFACE). In the receive data stream, real_digitizer.rcc worker makes symbol/bit decisions and only sends out bits that occur after the first detected 0xFACE bit pattern (b1111101011001110). The image is also padded with 40 bytes of zeros. This padding ensures that all image data is pushed through the signal processing chain.

5.2 Sample test setup

The test setup varies per mode of operation. The base test setup includes a hardware platform of choice and appropriate power and USB cables (Matchstiq-Z1 uses the USB cable to access the terminal via a program such as *screen* or over a USB-over-Ethernet connection; Stratix IV and ML605 require a USB cable for JTAG loading). All other test modes expand upon this base configuration, and may or may not include additional RF cabling or external equipment.

The *filerw* mode requires only the base test setup since no transceiver operations are actuated (data passes to and from the FPGA in a "loopback" fashion). Upon application execution, the expected result is written to odata/out_app_fsk_filerw.bin, which is a transmitted copy of the input file idata/Os.jpeg, without the prepended synchronizing pattern.

The *bbloopback* mode is similar to the *filerw* mode, but data goes beyond the FPGA through the radio's built-in analog baseband loopback, and back into the FPGA. Because the data never reaches the TX/RX connectors, no external RF cabling is required. The expected result is a transmitted copy of the idata/Os.jpeg file as the output odata/out_app_fsk_bbloopback.bin, without the prepended synchronizing pattern. Since this test is executed for a duration, rather than total image recognition, it is not uncommon that the output file will be larger than the actual size of the input image.

The next mode is the *rx* mode, which requires the base test setup with an RX antenna, as well as another transmitter (such as another platform running the *tx* mode) in order to broadcast a known FSK signal. Optionally, a spectrum analyzer may be connected to the transmitter to visually verify that the signal being fed into the radio's RX input is an FSK signal at the correct RF frequency and bandwidth. The output is written to the file odata/out_app_fsk_rx.bin, without the prepended synchronizing pattern. Since this test is executed for a duration, rather than total image recognition, it is not uncommon that the output file will be larger than the actual size of the input image.

The next mode is the *tx* mode, which requires the base test setup with a TX antenna, as well as some hardware to verify the transmission, such as a spectrum analyzer or an additional radio running in *rx* mode. In this mode the input file idata/Os.jpeg is transmitted out of the RF TX output of the radio.

The final mode is the *txrx* mode. This mode requires a base test setup with either a SMA loopback cable connecting the TX output of the radio to the RX input of the radio, or separate RX/TX antennas if RF usage is desired. An

RF splitter can also be used to optionally connect a spectrum analyzer to the RF signal for visual verification. The default values for RF gain assume that an RF splitter is being used. The output is written to the file odata/out_app_fsk_txrx.bin, without the prepended synchronizing pattern. Since this test is executed for a duration, rather than total image recognition, it is not uncommon that the output file will be larger than the actual size of the input image.

5.3 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.

5.4 Artifacts

Before running the application, the location of the required deployable artifacts must be specified in the `OCPI_LIBRARY_PATH` environment variable. Separate artifacts are needed for each RCC worker, and one artifact for the required FPGA image. Furthermore, artifacts differ depending on which mode the application is to be run in. Appendix B includes a list of the artifacts required for each platform and mode.

5.5 Arguments to executable

There is only one required initial argument to the FSK App executable, which defines the mode of execution. There is an optional initial argument to the FSK App executable that defines whether or not to run in debug mode. The app prompts the user at runtime for additional values, which vary depending upon the selected mode of operation. Running the application without any arguments prints the usage instructions. The non-initial optional arguments prompt the user to override the default value(s), and primarily configure the RF front end of the given platform using one or more endpoint proxies.

The arguments to the executable are summarized in the following table:

Argument	Mode	Description
mode	n/a	filerw, rx, tx, txrx, bbloopback
debug_mode	optional - ‘d’ or blank	enables initial and final dump of all properties

The prompts performed by the executable are summarized in the following table:

Argument	Mode	Description
RF frontend (ML605 and zed only)	rx, txrx	zipper, FMCOMMS2, or FMCOMMS3
runtime	filerw, rx, tx, txrx, bbloopback	run time of application in seconds
rx_sample_rate	rx, txrx, bbloopback	RX RF sample rate in Msps
rx_rf_center_freq	rx, txrx, bbloopback	RX RF tuning frequency in MHz
rx_rf_bw	rx, txrx, bbloopback	RX RF bandwidth in MHz
rx_rf_gain	rx, txrx, bbloopback	RX RF gain in dB
rx_bb_bw	rx, txrx, bbloopback	RX baseband bandwidth in MHz
rx_bb_gain	rx, txrx, bbloopback	RX baseband gain in dB
rx_if_center_freq	rx, txrx, bbloopback	RX IF tuning frequency in MHz. 0 disables IF tuning
tx_sample_rate	tx, txrx, bbloopback	TX RF sample rate in Msps
tx_rf_center_freq	tx, txrx, bbloopback	TX RF tuning frequency in MHz
tx_rf_gain	tx, txrx, bbloopback	TX RF gain in dB
tx_bb_bw	tx, txrx, bbloopback	TX baseband bandwidth in MHz
tx_bb_gain	tx, txrx, bbloopback	TX baseband gain in dB

Example arguments for the **FMCOMMS2** card using the txrx mode with an SMA loopback cable between FMCOMMS2 SMA ports RX1A and TX1A:

Parameter	Value
RF frontend	FMCOMMS2
Runtime (s)	20
RX SMA channel	RX1A
TX SMA channel	TX1A
rx_sample_rate	4
rx_rf_center_freq	2400 (default)
rx_rf_bw	-1 (default)
rx_rf_gain	24
rx_bb_bw	4
rx_bb_gain	-1 (default)
rx_if_center_freq	0
tx_sample_rate	4
tx_rf_center_freq	2400 (default)
tx_rf_bw	-1 (default)
tx_rf_gain	-34
tx_bb_bw	4
tx_bb_gain	-1 (default)

Example arguments for the **FMCOMMS3** card using the txrx mode with an SMA loopback cable between FMCOMMS3 SMA ports RX1A and TX1A:

Parameter	Value
RF frontend	FMCOMMS3
Runtime (s)	20
RX SMA channel	RX1A
TX SMA channel	TX1A
rx_sample_rate	4
rx_rf_center_freq	2400 (default)
rx_rf_bw	-1 (default)
rx_rf_gain	24
rx_bb_bw	4
rx_bb_gain	-1 (default)
rx_if_center_freq	0
tx_sample_rate	4
tx_rf_center_freq	2400 (default)
tx_rf_bw	-1 (default)
tx_rf_gain	-34
tx_bb_bw	4
tx_bb_gain	-1 (default)

5.6 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.

Note that the Stratix IV GX230 and ML605 hardware setups require the intended slot-specific bitstream's file location to be first in OCPI_LIBRARY_PATH. This is necessary because ocpirun's aritifact compatibility test does not currently differentiate between slot-connected device workers for multiple bitstreams that contain the same device worker, in the scenario where what differentiates the bitstreams is the device worker's slot connectivity.

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

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

- It is assumed (for PCI/host platforms) that the `core` and `assets` projects are named as such and exist in the same parent directory.

Recommended Library Path for Matchstiq-Z1 or Zedboard

For these platforms, 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/.

Recommended Library Path *filerw* mode for all host/PCI platforms

```
OCPI_LIBRARY_PATH=../../core/artifacts:../../artifacts
```

Recommended Library Path for ML605/FMCOMMS2/3-HPC

Not Supported

Recommended Library Path for ML605/FMCOMMS2/3-LPC

```
OCPI_LIBRARY_PATH=../../core/artifacts:../../artifacts
```

5.7 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 4.

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 5.

Figure 4: FSK input file

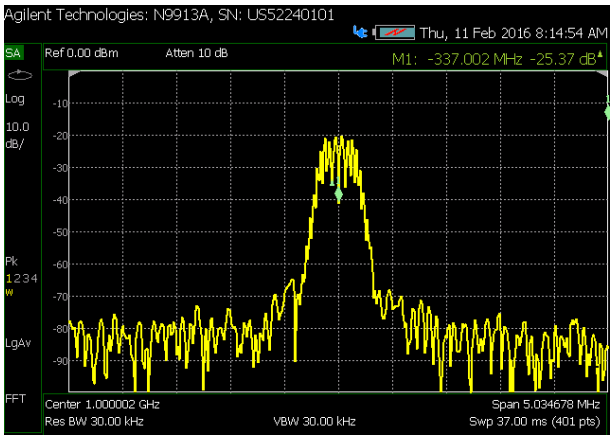

Figure 5: Output of FSK App RF transmit

5.8 Known Issues

- The demodulation algorithm currently suffers from limited carrier recovery ability which can cause the output image to be corrupted or non-existent when using the *rx* or *txrx* mode. If using an SMA loopback for txrx mode on an RF transceiver where the RX and TX data stream's LOs are sourced by the same clock, carrier recovery is not expected to be an issue.

6 Appendix A: Worker Parameters

Common to all hardware

- dc_offset_filter.hdl
  - DATA_WIDTH_p = 16
  - PEAK_MONITOR_p = true
- iq_imbalance_fixer.hdl
  - DATA_WIDTH_p = 16
  - ACC_PREC_p = 38
  - PEAK_MONITOR_p = true
- complex_mixer.hdl
  - CHIPSCOPE_p = false
  - NCO_DATA_WIDTH_p = 12
  - INPUT_DATA_WIDTH_p = 12
  - CORDIC_STAGES_p = 16
  - PEAK_MONITOR_p = true
- cic_dec.hdl
  - N = 3
  - M = 1
  - R = 16
  - DIN_WIDTH = 16
  - ACC_WIDTH = 28
  - DOUT_WIDTH = 16
- rp_cordic.hdl
  - DATA_WIDTH = 16
  - DATA_EXT = 6
  - STAGES = 16
- fir_real_sse.hdl (rx_fir_real)
  - NUM_TAPS_p = 64
  - DATA_WIDTH_p = 16
  - COEFF_WIDTH_p = 16
- mfsk_mapper.hdl
  - M_p = 2
- zero_pad.hdl
  - DWIDTH_p = 16

ML605 (with FMCOMMS2/3 card in FMC HPC slot)

- fmcomms_2_3_i2c.hdl
  - CP_CLK_FREQ_p = 125e6
  - FMC_GA1 = 0
  - FMC_GA0 = 0
- ad9361_spi.hdl
  - CP_CLK_FREQ_HZ_p = 125e6
- ad9361_data_sub.hdl
  - LVDS_p = true
  - DATA_CLK_Delay = 2
  - RX_Data_Delay = 0
  - FB_CLK_Delay = 7
  - TX_Data_Delay = 0

ML605 (with FMCOMMS2/3 card in FMC LPC slot)

- fmcomms_2_3_i2c.hdl
  - CP_CLK_FREQ_p = 125e6
  - FMC_GA1 = 1
  - FMC_GA0 = 0
- ad9361_spi.hdl
  - CP_CLK_FREQ_HZ_p = 125e6
- ad9361_data_sub.hdl
  - LVDS_p = true
  - DATA_CLK_Delay = 2
  - RX_Data_Delay = 0
  - FB_CLK_Delay = 7
  - TX_Data_Delay = 0

Zedboard FMCOMMS2/3 configurations)

- fmcomms_2_3_i2c.hdl
  - CP_CLK_FREQ_p = 100e6
  - FMC_GA1 = 0
  - FMC_GA0 = 0
- ad9361_spi.hdl
  - CP_CLK_FREQ_HZ_p = 100e6
- ad9361_data_sub.hdl
  - LVDS_p = true
  - DATA_CLK_Delay = 2
  - RX_Data_Delay = 0
  - FB_CLK_Delay = 7
  - TX_Data_Delay = 0

Matchstiq-Z1 configurations

- lime_adc.hdl
  - DRIVE_CLK_p = false
  - USE_CLK_IN_p = false
  - USE_CTL_CLK_p = false
  - USE_CLK_OUT_p = true
- si5338.hdl
  - CLKIN_PRESENT_p = true
  - CLKIN_FREQ_p = 3.072e7
  - XTAL_PRESENT_p = false
  - XTAL_FREQ_p = 0
  - OUTPUTS_PRESENT_p = true, false
  - INTR_CONNECTED_p = false
- matchstiq_z1_i2c.hdl
  - NUSERS_p = 5
  - SLAVE_ADDRESS_p = 0x45, 0x71, 0x48, 0x21, 0x20
  - CLK_CNT_p = 199

Zipper-related platforms (Zedboard, Stratix IV, ML605)

- lime_adc.hdl
  - DRIVE_CLK_p = false
  - USE_CLK_IN_p = true
  - USE_CTL_CLK_p = false
  - USE_CLK_OUT_p = false
- si5351.hdl
  - CLKIN_PRESENT = true
  - CLKIN_FREQ = 3.072e7
  - XTAL_PRESENT = false
  - XTAL_FREQ = 0
  - VC_PRESENT = false
  - OUTPUTS_PRESENT = 0,0,1,1,1,1,0,0
  - OEB_MODE = low
  - INTR_CONNECTED = false
- zipper_i2c.hdl
  - NUSERS_p = 2

7 Appendix B: Artifacts

7.1 Zedboard/FMCOMMS2/3

filerw (FMCOMMS2/3 not required)

- fsk_filerw_zed_base.bitz
- target-xilinx13_3/file_read.so
- target-xilinx13_3/Baudtracking_simple.so
- target-xilinx13_3/real_digitizer.so
- target-xilinx13_3/file_write.so

rx

- dc_offset_iq_imbalance_mixer_cic_dec_timestamper_zed_cfg_1rx_0 tx_fmcomms_2_3_lpc_lvds_cnt_1rx_0tx_thruasm_fmcomms_2_3_lpc_LVDS_zed.bitz
- target-xilinx13_3/Baudtracking_simple.so
- target-xilinx13_3/real_digitizer.so
- target-xilinx13_3/file_write.so
- target-xilinx13_3/ad9361_config_proxy.so
- target-xilinx13_3/fmcomms_2_3_rx.so

tx

- mfsk2_zp16_fir_real_phase_to_amp_cordic_cic_int_zed_cfg_0rx_ 1tx_fmcomms_2_3_lpc_lvds_cnt_0rx_1tx_thruasm_fmcomms_2_3_lpc_LVDS_zed.bitz
- target-xilinx13_3/file_read.so
- target-xilinx13_3/zipper_tx.so
- target-xilinx13_3/ad9361_config_proxy.so
- target-xilinx13_3/fmcomms_2_3_tx.so

txrx

- fsk_modem_zed_cfg_1rx_1tx_fmcomms_2_3_lpc_lvds_cnt_1rx_1tx_ thruasm_fmcomms_2_3_lpc_LVDS_zed.bitz
- target-xilinx13_3/file_read.so
- target-xilinx13_3/Baudtracking_simple.so
- target-xilinx13_3/real_digitizer.so
- target-xilinx13_3/file_write.so
- target-xilinx13_3/ad9361_config_proxy.so
- target-xilinx13_3/fmcomms_2_3_rx.so
- target-xilinx13_3/fmcomms_2_3_tx.so

7.2 Matchstiq-Z1

filerw

- fsk_filerw_matchstiq_z1_base.bitz
- target-xilinx13_3/file_read.so
- target-xilinx13_3/Baudtracking_simple.so
- target-xilinx13_3/real_digitizer.so
- target-xilinx13_3/file_write.so

rx

- dc_offset_iq_imbalance_mixer_cic_dec_rp_cordic_fir_real_matchstiq_z1_matchstiq_z1_rx_cnt_1rx_0tx_thruasm_matchstiq_z1.bitz
- target-xilinx13_3/Baudtracking_simple.so
- target-xilinx13_3/real_digitizer.so
- target-xilinx13_3/file_write.so
- target-xilinx13_3/matchstiq_z1_rx.so
- target-xilinx13_3/lime_rx_proxy.so
- target-xilinx13_3/si5338_proxy.so
- target-xilinx13_3/matchstiq_z1_avr_proxy.so
- target-xilinx13_3/tmp100_proxy.so
- target-xilinx13_3/matchstiq_z1_pca9535_proxy.so

tx

- mfsk2_zp16_fir_real_phase_to_amp_cordic_cic_int_matchstiq_z1_matchstiq_z1_tx_cnt_0rx_1tx_thruasm_matchstiq_z1.bitz
- target-xilinx13_3/file_read.so
- target-xilinx13_3/matchstiq_z1_tx.so
- target-xilinx13_3/lime_tx_proxy.so
- target-xilinx13_3/si5338_proxy.so
- target-xilinx13_3/matchstiq_z1_avr_proxy.so
- target-xilinx13_3/tmp100_proxy.so
- target-xilinx13_3/matchstiq_z1_pca9535_proxy.so

txrx/bbloopback

- fsk_modem_matchstiq_z1_matchstiq_z1_rx_tx_cnt_1rx_1tx_thruasm_matchstiq_z1.bitz
- target-xilinx13_3/file_read.so
- target-xilinx13_3/Baudtracking_simple.so
- target-xilinx13_3/real_digitizer.so
- target-xilinx13_3/file_write.so
- target-xilinx13_3/matchstiq_z1_rx.so
- target-xilinx13_3/matchstiq_z1_tx.so
- target-xilinx13_3/lime_rx_proxy.so
- target-xilinx13_3/lime_tx_proxy.so
- target-xilinx13_3/si5338_proxy.so
- target-xilinx13_3/matchstiq_z1_avr_proxy.so
- target-xilinx13_3/tmp100_proxy.so
- target-xilinx13_3/matchstiq_z1_pca9535_proxy.so

7.3 ML605/FMCOMMS2/3

filerw (FMCOMMS2/3 not required)

- fsk_filerw_ml605_base.bitz
- target-centos7/file_read.so
- target-centos7/Baudtracking_simple.so
- target-centos7/real_digitizer.so
- target-centos7/file_write.so

rx

- target-centos7/file_read.so
- target-centos7/Baudtracking_simple.so
- target-centos7/real_digitizer.so
- target-centos7/ad9361_config_proxy.so
- target-centos7/fmcomms_2_3_rx.so

For FMCOMMS2/3 plugged into FMC LPC:

- dc_offset_iq_imbalance_mixer_cic_dec_timestamper_ml605_cfg_1rx_0tx_fmcomms_2_3_lpc_lvds_cnt_1rx_0tx_thruasm_fmcomms_2_3_lpc_LVDS_ml605.bitz

For FMCOMMS2/3 plugged into FMC HPC:

- dc_offset_iq_imbalance_mixer_cic_dec_timestamper_ml605_cfg_1rx_0tx_fmcomms_2_3_hpc_lvds_cnt_1rx_0tx_thruasm_fmcomms_2_3_hpc_LVDS_ml605.bitz

tx

- target-centos7/file_read.so
- target-centos7/ad9361_config_proxy.so
- target-centos7/fmcomms_2_3_tx.so

txrx

- target-centos7/file_read.so
- target-centos7/Baudtracking_simple.so
- target-centos7/real_digitizer.so
- target-centos7/ad9361_config_proxy.so
- target-centos7/fmcomms_2_3_rx.so
- target-centos7/fmcomms_2_3_tx.so

8 Appendix C: Deprecated Zipper

Beginning with OpenCPI Version 1.5, Support for Lime Microsystems' Zipper card is now deprecated, and the following have been removed from the main body of this document:

8.1 Supported Hardware Setups

This app is supported on the following hardware configurations:

- Zedboard/Zipper/MyriadRF
- x86/Stratix IV GX development kit (230 Edition)/Zipper/MyriadRF in HSMC A slot
- x86/Stratix IV GX development kit (230 Edition)/Zipper/MyriadRF in HSMC B slot
- x86/ML605/Zipper/MyriadRF in FMC LPC slot
- x86/ML605/Zipper/MyriadRF in FMC HPC slot

8.2 Known Issues

- For more information on known limitations when using the Zipper-related platforms (Zedboard, Stratix IV, ML605), see the document Myriad-RF_1_Zipper_Limitations included with this project.
- On x86 host machines with more than one Stratix IV and/or ML605s plugged into PCIe slots, this app will assume that the first found Stratix IV/ML605 has a Zipper/MyriadRF plugged in. The first found Stratix IV/ML605 will be used during execution. While there are means to address this issue, they have not been implemented for the current release.

8.3 Additional Dependencies for Zipper-related platforms (Zedboard, Stratix IV, ML605)

Application XML	filerw	rx	tx	txrx	bbloopback
app_fsk_rx_zipper (dependency only, no build required)		x			
app_fsk_tx_zipper (dependency only, no build required)			x		
app_fsk_txrx_zipper (dependency only, no build required)				x	x
RX Path Workers	filerw	rx	tx	txrx	bbloopback
lime_adc.hdl		x		x	x
TX Path Workers	filerw	rx	tx	txrx	bbloopback
lime_dac.hdl			x	x	x
Endpoint Proxies	filerw	rx	tx	txrx	bbloopback
zipper_rx.rcc		x		x	x
zipper_tx.rcc			x	x	x
SPI Command and Control	filerw	rx	tx	txrx	bbloopback
lime_rx_proxy.rcc		x		x	x
lime_rx.hdl		x		x	x
lime_tx_proxy.rcc			x	x	x
lime_tx.hdl			x	x	x
lime_spi.hdl		x	x	x	x
I2C Command and Control	filerw	rx	tx	txrx	bbloopback
si5351_proxy.rcc		x	x	x	x
si5351.hdl		x	x	x	x

8.4 Zipper Recommended Library Path

Recommended Library Path for Stratix IV GX230/Zipper in HSMC A

rx

```
OCPI_LIBRARY_PATH=../../artifacts/ocpi.assets.dc_offset_iq_imbalance_mixer_cic_dec_\
rp_cordic_fir_real_alst4_alst4_zipper_hsmc_alst4_port_a_rx_cnt_1rx_0tx_thruasm_zipper_\
hsmc_a_alst4.hdl.0.alst4.gz\
:../../core/artifacts:../../artifacts
```

tx

```
OCPI_LIBRARY_PATH=../../artifacts/ocpi.assets.mfsk2_zp16_fir_real_phase_to_amp_cordic_cic_int_\
alst4_alst4_zipper_hsmc_alst4_port_a_tx_cnt_0rx_1tx_thruasm_zipper_hsmc_a_alst4.hdl.0.alst4.gz\
:../../core/artifacts:../../artifacts
```

txrx/bbloopback

```
OCPI_LIBRARY_PATH=../../artifacts/ocpi.assets.fsk_modem_alst4_alst4_zipper_hsmc_alst4_\
port_a_rx_tx_cnt_1rx_1tx_thruasm_zipper_hsmc_a_alst4.hdl.0.alst4.gz\
:../../core/artifacts:../../artifacts
```

Recommended Library Path for Stratix IV GX230/Zipper in HSMC B

rx

```
OCPI_LIBRARY_PATH=../../artifacts/ocpi.assets.dc_offset_iq_imbalance_mixer_cic_dec_rp_cordic_fir\
_real_alst4_alst4_zipper_hsmc_alst4_port_b_rx_cnt_1rx_0tx_thruasm_zipper_hsmc_b_alst4.hdl.0.alst4.gz\
:../../../core/artifacts:../../artifacts
```

tx

```
OCPI_LIBRARY_PATH=../../artifacts/ocpi.assets.mfsk2_zp16_fir_real_phase_to_amp_cordic_cic_int\
_alst4_alst4_zipper_hsmc_alst4_port_b_tx_cnt_0rx_1tx_thruasm_zipper_hsmc_b_alst4.hdl.0.alst4.gz\
:../../../core/artifacts:../../artifacts
```

txrx/bbloopback

```
OCPI_LIBRARY_PATH=../../artifacts/ocpi.assets.fsk_modem_alst4_alst4_zipper_hsmc_alst4_\
port_b_rx_tx_cnt_1rx_1tx_thruasm_zipper_hsmc_b_alst4.hdl.0.alst4.gz\
:../../../core/artifacts:../../artifacts
```

Recommended Library Path for ML605/Zipper in FMC LPC

rx

```
OCPI_LIBRARY_PATH=../../artifacts/ocpi.assets.dc_offset_iq_imbalance_mixer_cic_dec_rp_cordic\
_fir_real_ml605_ml605_zipper_fmc_lpc_rx_cnt_1rx_0tx_thruasm_zipper_lpc_ml605.hdl.0.ml605.gz\
:../../../core/artifacts:../../artifacts
```

tx

```
OCPI_LIBRARY_PATH=../../artifacts/ocpi.assets.fsk_modem_ml605_ml605\
_zipper_fmc_lpc_rx_tx_cnt_1rx_1tx_thruasm_zipper_lpc_ml605.hdl.0.ml605.gz\
:../../../core/artifacts:../../artifacts
```

txrx/bbloopback

```
OCPI_LIBRARY_PATH=../../artifacts/ocpi.assets.fsk_modem_ml605_ml605\
_zipper_fmc_lpc_rx_tx_cnt_1rx_1tx_thruasm_zipper_lpc_ml605.hdl.0.ml605.gz\
:../../../core/artifacts:../../artifacts
```

Example ML605/Zipper in FMC HPC

rx

```
OCPI_LIBRARY_PATH=../../artifacts/ocpi.assets.dc_offset_iq_imbalance_mixer_cic_dec_rp_cordic\
_fir_real_ml605_ml605_zipper_fmc_hpc_rx_cnt_1rx_0tx_thruasm_zipper_hpc_ml605.hdl.0.ml605.gz\
:../../../core/artifacts:../../artifacts
```

tx

```
OCPI_LIBRARY_PATH=../../artifacts/ocpi.assets.mfsk2_zp16_fir_real_phase_to_amp_cordic_cic_int\
_ml605_ml605_zipper_fmc_hpc_tx_cnt_0rx_1tx_thruasm_zipper_hpc_ml605.hdl.0.ml605.gz\
:../../../core/artifacts:../../artifacts
```

txrx/bbloopback

```
OCPI_LIBRARY_PATH=../../artifacts/ocpi.assets.fsk_modem_ml605_ml605\
_zipper_fmc_hpc_rx_tx_cnt_1rx_1tx_thruasm_zipper_hpc_ml605.hdl.0.ml605.gz\
:../../../core/artifacts:../../artifacts
```

8.5 Artifacts: Zedboard/Zipper

filerw (zipper not required)

- fsk_filerw_zed_base.bitz
- target-xilinx13_3/file_read.so
- target-xilinx13_3/Baudtracking_simple.so
- target-xilinx13_3/real_digitizer.so
- target-xilinx13_3/file_write.so

rx

- dc_offset_iq_imbalance_mixer_cic_dec_rp_cordic_fir_real_zed_base_cnt_1rx_0tx_thruasm_zipper_lpc_zed.bitz
- target-xilinx13_3/Baudtracking_simple.so
- target-xilinx13_3/real_digitizer.so
- target-xilinx13_3/file_write.so
- target-xilinx13_3/zipper_rx.so
- target-xilinx13_3/lime_rx_proxy.so
- target-xilinx13_3/si5351_proxy.so

tx

- mfsk2_zp16_fir_real_phase_to_amp_cordic_cic_int_zed_base_cnt_0rx_1tx_thruasm_zipper_lpc_zed.bitz
- target-xilinx13_3/file_read.so
- target-xilinx13_3/zipper_tx.so
- target-xilinx13_3/lime_tx_proxy.so
- target-xilinx13_3/si5351_proxy.so

txrx/bbloopback

- fsk_modem_zed_base_cnt_1rx_1tx_thruasm_zipper_lpc_zed.bitz
- target-xilinx13_3/file_read.so
- target-xilinx13_3/Baudtracking_simple.so
- target-xilinx13_3/real_digitizer.so
- target-xilinx13_3/file_write.so
- target-xilinx13_3/zipper_rx.so
- target-xilinx13_3/zipper_tx.so
- target-xilinx13_3/lime_rx_proxy.so
- target-xilinx13_3/lime_tx_proxy.so
- target-xilinx13_3/si5351_proxy.so

8.6 Artifacts: Stratix IV/Zipper

filerw (zipper not required)

- fsk_filerw_alst4_base.bitz
- target-centos7/file_read.so
- target-centos7/Baudtracking_simple.so
- target-centos7/real_digitizer.so
- target-centos7/file_write.so

rx

- target-centos7/file_read.so
- target-centos7/Baudtracking_simple.so
- target-centos7/real_digitizer.so
- target-centos7/zipper_rx.so
- target-centos7/lime_rx_proxy.so
- target-centos7/si5351_proxy.so

For Zipper plugged into HSMC Port A:

- dc_offset_iq_imbalance_mixer_cic_dec_rp_cordic_fir_real_alst4_alst4_zipper_hsmc_alst4_port_a_rx_cnt_1rx_0tx_thruasm_zipper_hsmc_a_alst4.bitz

For Zipper plugged into HSMC Port B:

- dc_offset_iq_imbalance_mixer_cic_dec_rp_cordic_fir_real_alst4_alst4_zipper_hsmc_alst4_port_b_rx_cnt_1rx_0tx_thruasm_zipper_hsmc_b_alst4.bitz

tx

- target-centos7/file_read.so
- target-centos7/zipper_tx.so
- target-centos7/lime_tx_proxy.so
- target-centos7/si5351_proxy.so

For Zipper plugged into HSMC Port A:

- mfsk2_zp16_fir_real_phase_to_amp_cordic_cic_int_alst4_alst4_zipper_hsmc_alst4_port_a_txcnt_0rx_1tx_thruasm_zipper_hsmc_a_alst4.bitz

For Zipper plugged into HSMC Port B:

- mfsk2_zp16_fir_real_phase_to_amp_cordic_cic_int_alst4_alst4_zipper_hsmc_alst4_port_b_tx_cnt_0rx_1tx_thruasm_zipper_hsmc_b_alst4.bitz

txrx/bbloopback

- target-centos7/file_read.so
- target-centos7/Baudtracking_simple.so
- target-centos7/real_digitizer.so
- target-centos7/zipper_rx.so
- target-centos7/zipper_tx.so
- target-centos7/lime_rx_proxy.so
- target-centos7/lime_tx_proxy.so
- target-centos7/si5351_proxy.so

For Zipper plugged into HSMC Port A:

- fsk_modem_alst4_alst4_zipper_hsmc_alst4_port_a_rx_tx_cnt_1rx_1tx_thruasm_zipper_hsmc_a_alst4.bitz

For Zipper plugged into HSMC Port B:

- fsk_modem_alst4_alst4_zipper_hsmc_alst4_port_b_rx_tx_cnt_1rx_1tx_thruasm_zipper_hsmc_b_alst4.bitz

8.7 Artifacts: ML605/Zipper

filerw (zipper not required)

- fsk_filerw_ml605_base.bitz
- target-centos7/file_read.so
- target-centos7/Baudtracking_simple.so
- target-centos7/real_digitizer.so
- target-centos7/file_write.so

rx

- target-centos7/file_read.so
- target-centos7/Baudtracking_simple.so
- target-centos7/real_digitizer.so
- target-centos7/zipper_rx.so
- target-centos7/lime_rx_proxy.so
- target-centos7/si5351_proxy.so

For Zipper plugged into FMC LPC:

- dc_offset_iq_imbalance_mixer_cic_dec_rp_cordic_fir_real_ml605_cfg_1rx_0tx_fmcomms_2_3_lpc_lvds_cnt_1rx_0tx_thruasm_fmcomms_2_3_lpc_LVDS_ml605.bitz

For Zipper plugged into FMC HPC:

- dc_offset_iq_imbalance_mixer_cic_dec_rp_cordic_fir_real_ml605_cfg_1rx_0tx_fmcomms_2_3_hpc_lvds_cnt_1rx_0tx_thruasm_fmcomms_2_3_hpc_LVDS_ml605.bitz

tx

- target-centos7/file_read.so
- target-centos7/zipper_tx.so
- target-centos7/lime_tx_proxy.so
- target-centos7/si5351_proxy.so

For Zipper plugged into FMC LPC:

- mfsk2_zp16_fir_real_phase_to_amp_cordic_cic_int_ml605_ml605_zipper_fmc_lpc_tx_cnt_0rx_1tx_thruasm_zipper_lpc_ml605.bitz

For Zipper plugged into FMC HPC:

- mfsk2_zp16_fir_real_phase_to_amp_cordic_cic_int_ml605_ml605_zipper_fmc_hpc_tx_cnt_0rx_1tx_thruasm_zipper_hpc_ml605.bitz

txrx/bbloopback

- target-centos7/file_read.so
- target-centos7/Baudtracking_simple.so
- target-centos7/real_digitizer.so
- target-centos7/zipper_rx.so
- target-centos7/zipper_tx.so
- target-centos7/lime_rx_proxy.so
- target-centos7/lime_tx_proxy.so
- target-centos7/si5351_proxy.so

For Zipper plugged into FMC LPC:

- fsk_modem_ml605_ml605_zipper_fmc_hpc_rx_tx_cnt_1rx_1tx_thruasm_zipper_lpc_ml605.bitz

For Zipper plugged into FMC HPC:

- fsk_modem_ml605_ml605_zipper_fmc_hpc_rx_tx_cnt_1rx_1tx_thruasm_zipper_hpc_ml605.bitz