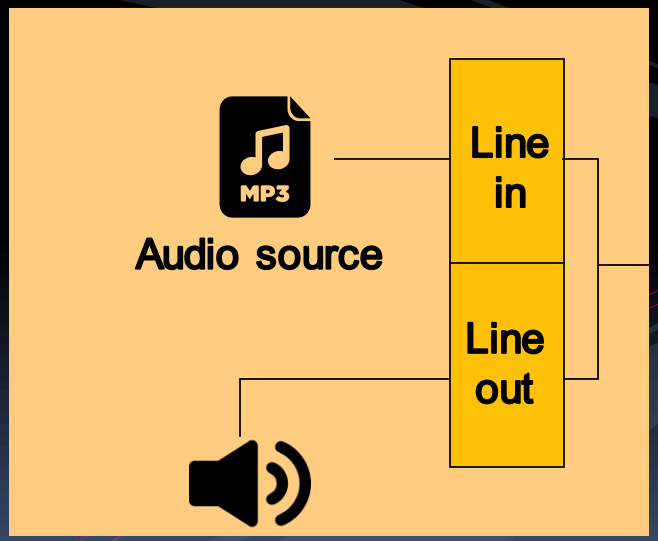
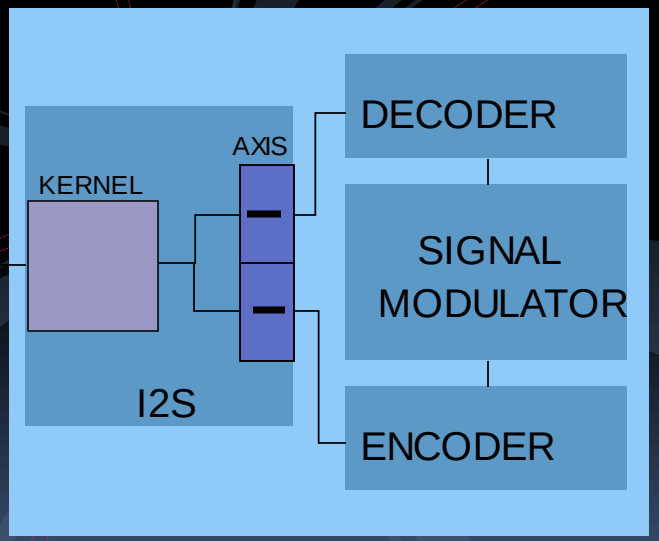
LAB3 OVERVIEW

Topics

Audio Source Sampling, I2S "Implementation", Encoder/Decoder, Signal Manipulation

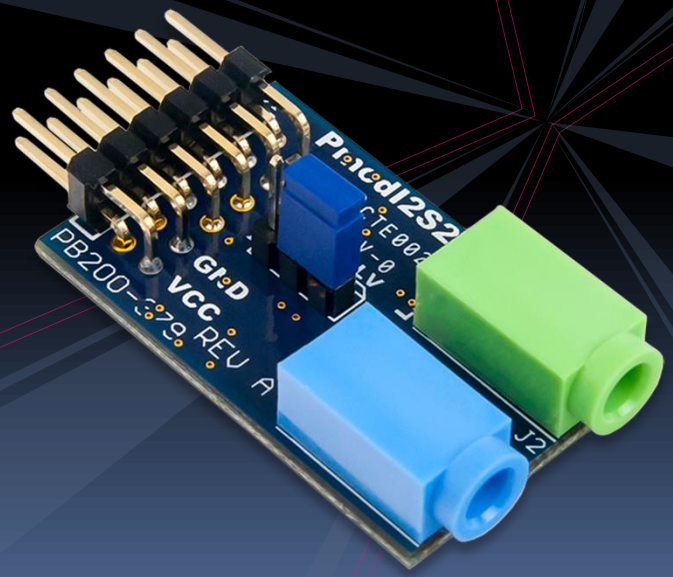




Home assignment

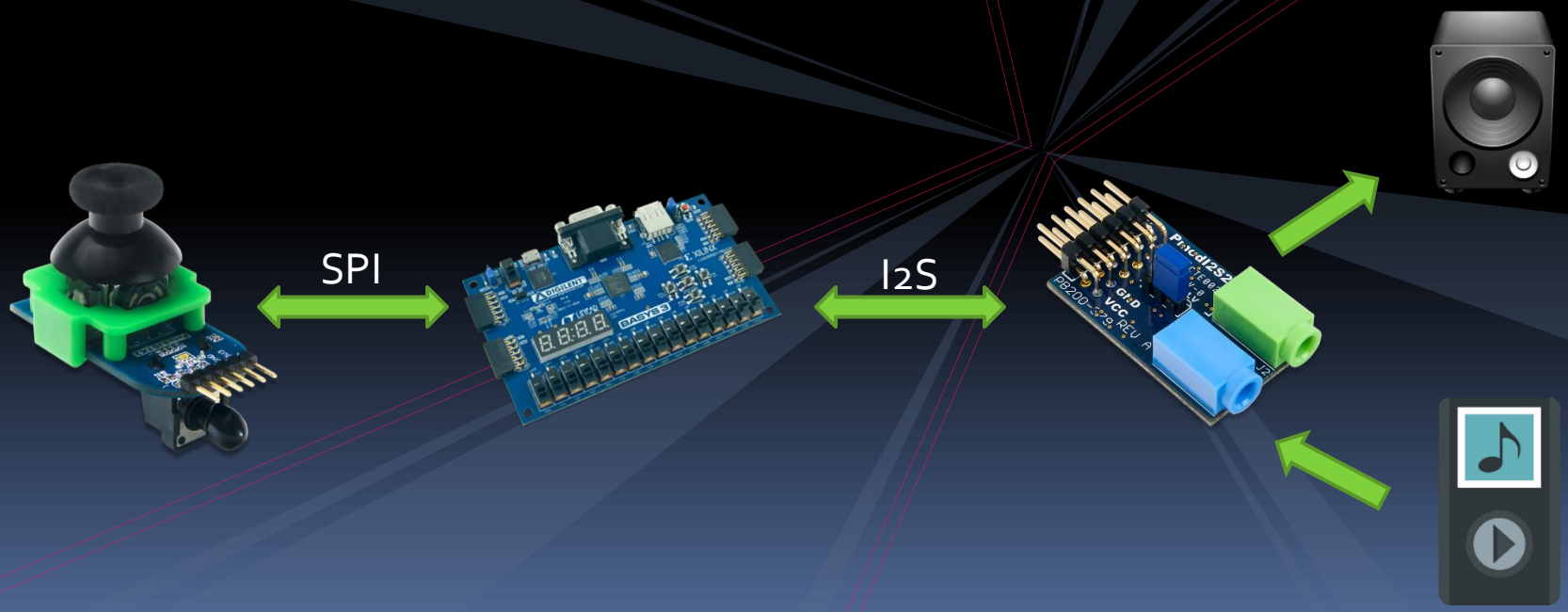
At the beginning of LAB3, we will give each one of you a Digilent Pmod I2S2 module.

This can be connected to your Basys3 board through the Pmod connectors.

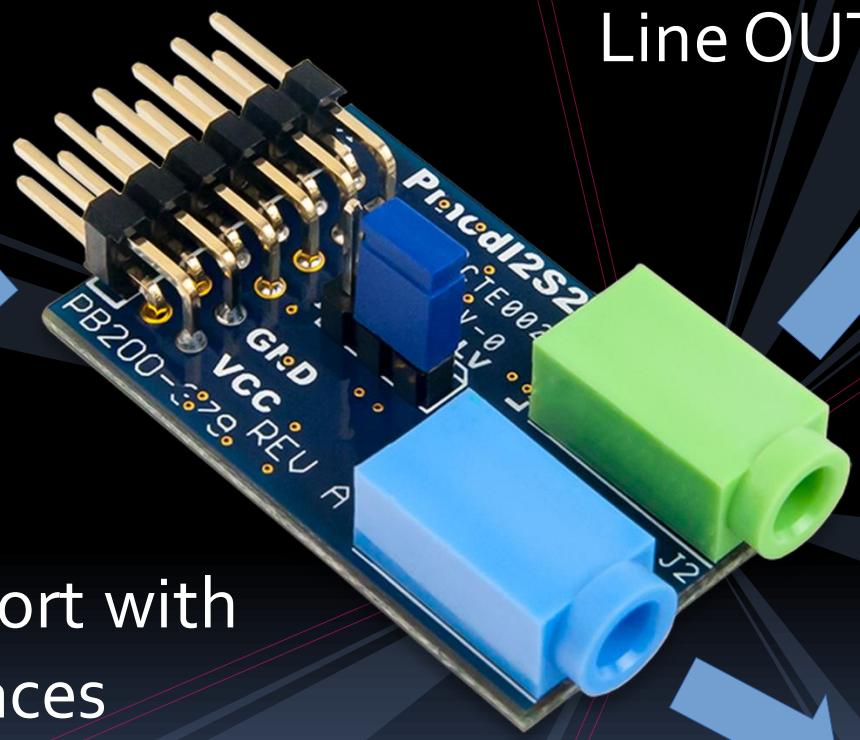


Home assignment Goal

The objective of the LAB3 home assignment is to build a "Digital Audio Console" by using the Pmod_I2S2, Pmod_JSTK2 modules and IP-Cores



Digilent Pmod I2S2 components



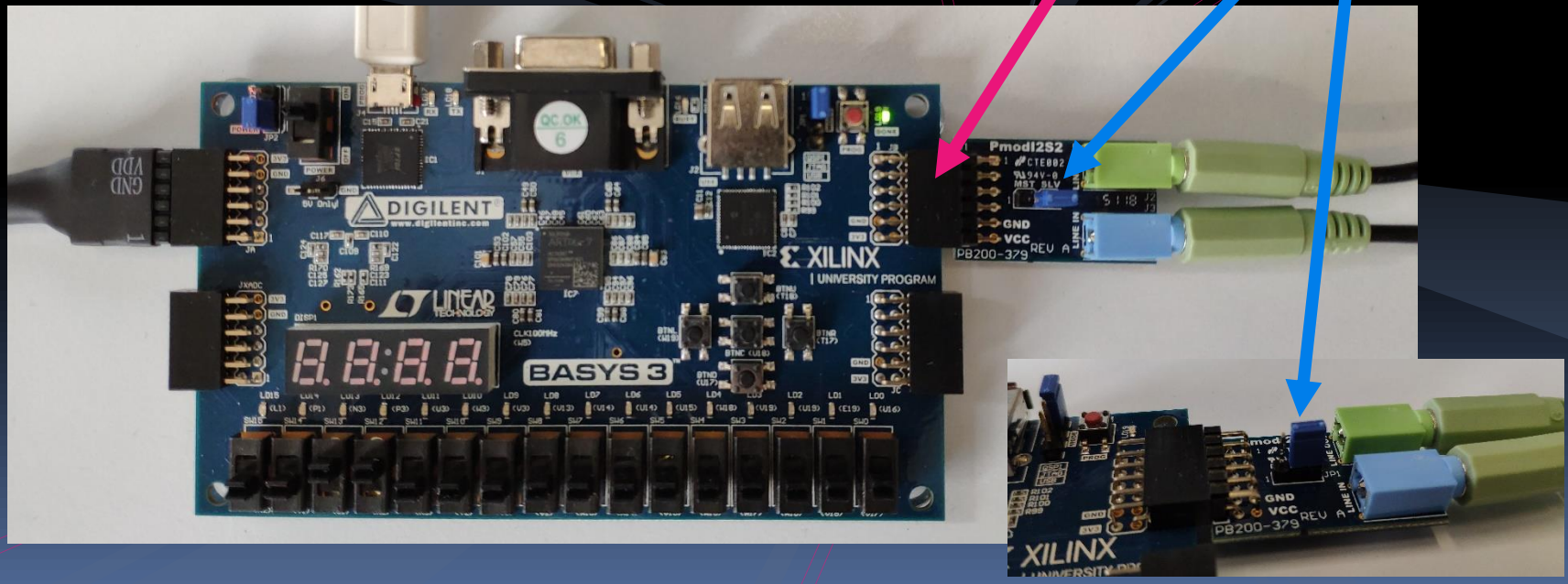
Line OUT (24 bit D/A)

12-pin Pmod Port with
two I2S interfaces

Line IN (24 bit A/D)

How to connect the I2S2 module

The provided constraints are for the JB connector (top right of the board). Also make sure that the jumper on the PmodI2S2 module is on the **SLV** position (right position).



Pmod I2S2 interfacing

The Digilent Pmod I2S2 module protocol is fully described in its reference manual.

In short, it uses the I2S protocol for both receiving an input audio signal from a source (through an ADC) and sending back an audio signal by means of a DAC to any kind of "speaker".

Audio Signal Format

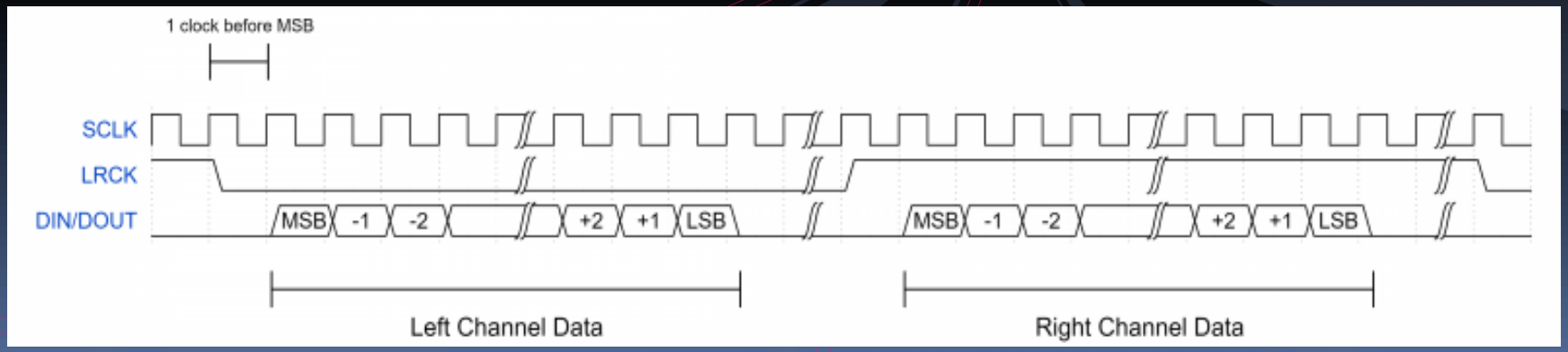
- Typical sound frequency passband of the ears is between 20 and 20KHz. (Shannon theorem => 44.1 Ksamples)
- For a good quality audio we choose a 24bits/channel depth.
  (we consider stereo audio: L/R channels)

I2S protocol

The Inter-IC Sound (I2S) is a popular serial protocol for digital audio devices connections.

In its basic form it is composed by 4 signals:

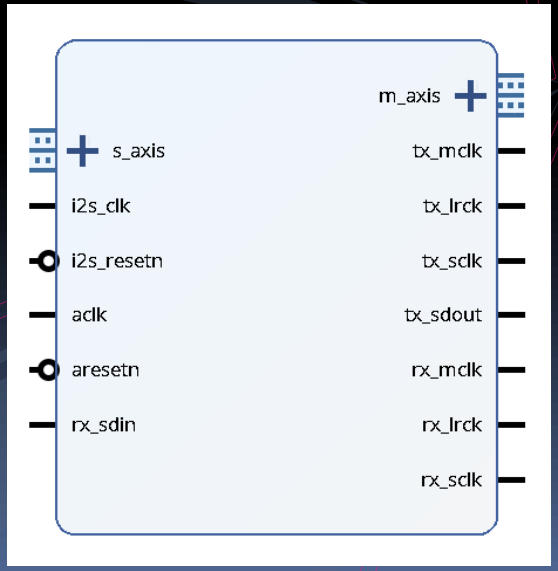
- Master CLocK (MCLK)
- Left/Right CLocK (LRCLK, aka Word Select)
- Serial CLocK (SCLK, aka Bit Clock)
- Din/Dout (for Line In/Line Out channels)



I2S IP-Core

While I2S is a simple protocol, describing it in VHDL is not immediate.

To ease your work, we will give you a "AXI4-Stream I2S2" IP-Core, similar to the SPI and UART ones.



I2S IP-Core

The provided Pmod-I2S2 IP-Core has:

- Two I2S interfaces, to be connected to the external pins of the FPGA.
- Two AXI4-Stream interfaces, to read the data from the ADC or to send the data to the DAC.
- Two clocks:
  - one for the I2S and (22.579 MHz)
  - one for the AXI4-Stream
- Two input active-low reset signals (one for each clock domain).

I2S IP-Core: 44.1 kHz Audio

The IP core needs a 22.579 MHz clock (to be connected to i2s_clk) and a 100 MHz clock (to be connected to every other clock input).

In details, for a 44.1 kHz audio sampling rate:

- MCLK = 22.579 MHz (I2S Clk of the IP-Core)
- SCLK = MCLK/8
- LRCLK = SCLK/64 = 44.1 kHz

Pmod-I2S2 AXI4-Stream format

The AXI4-Stream interface has an additional line called **TLAST**, which is used to determine the end of a packet.

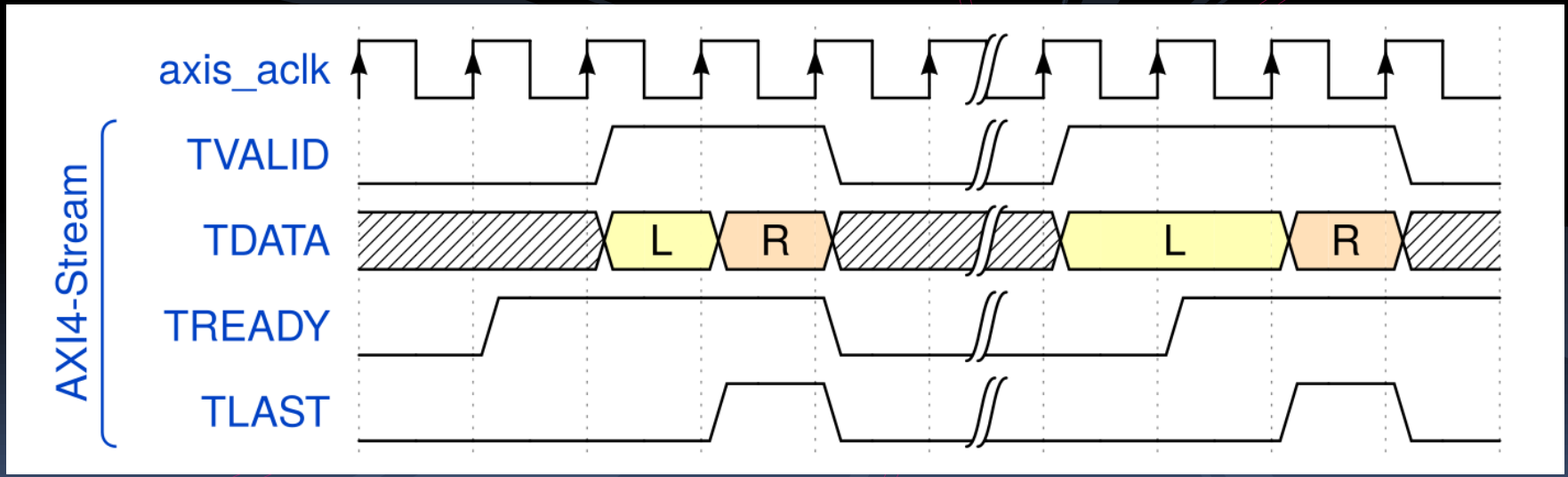
Each packet is composed by two 24-bits words: the first one is the audio data of the left channel, the second one the audio data of the right one.

TLAST is asserted on the second word; in other words:

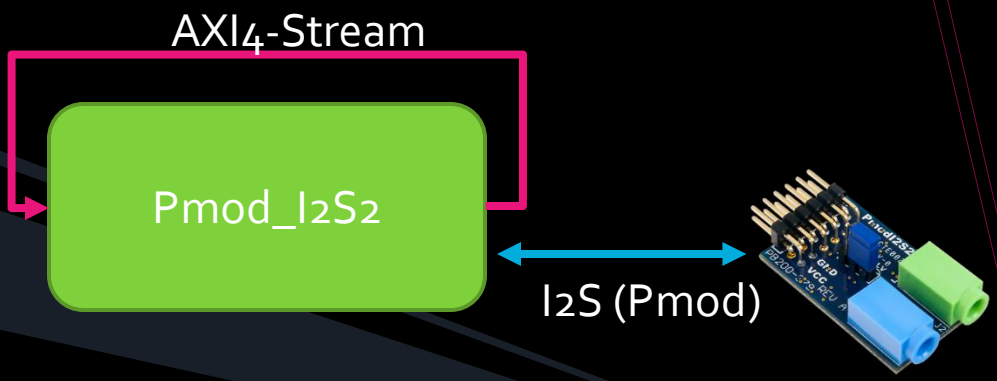
- TLAST = 0: left channel
- TLAST = 1: right channel

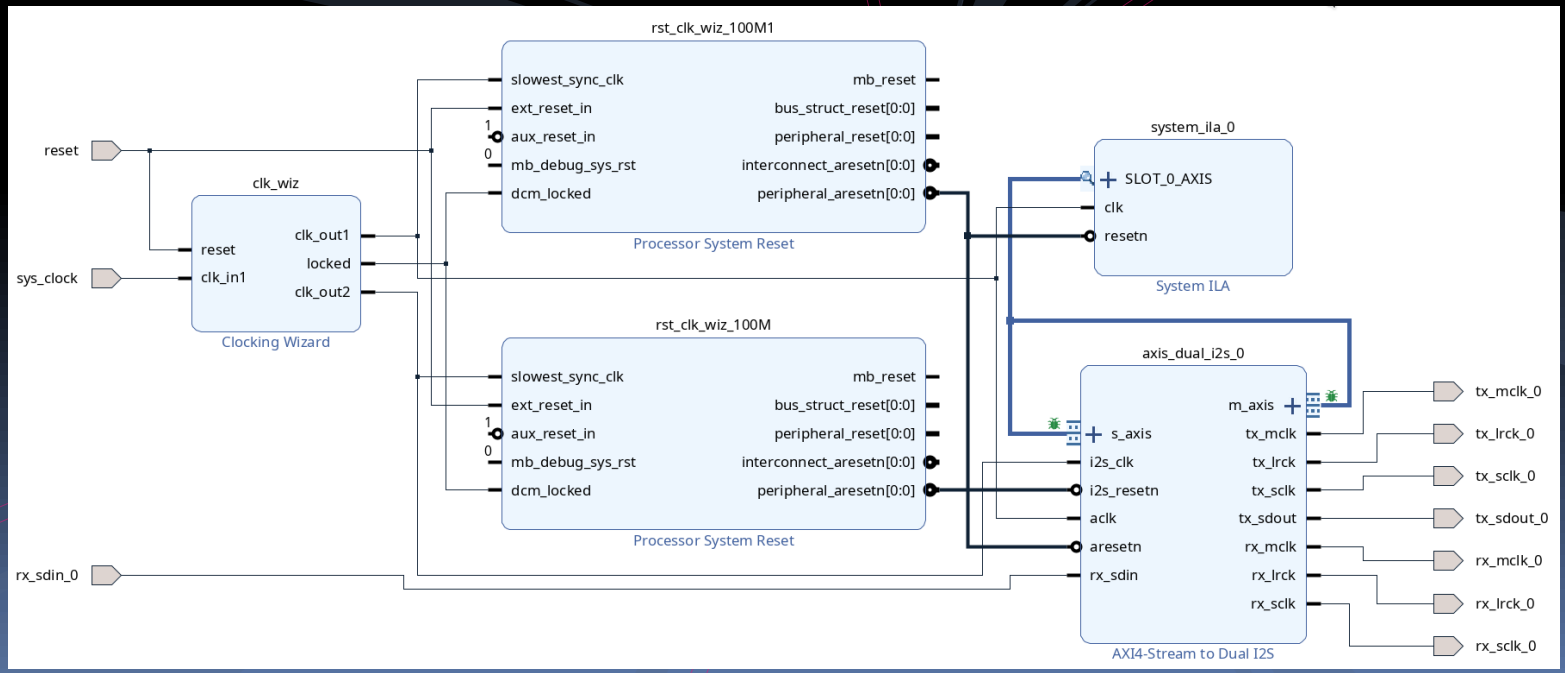
Pmod-I2S2 AXI4-Stream format

In this example, two «packets» have been transferred, first the left channel and then the right one for each one.

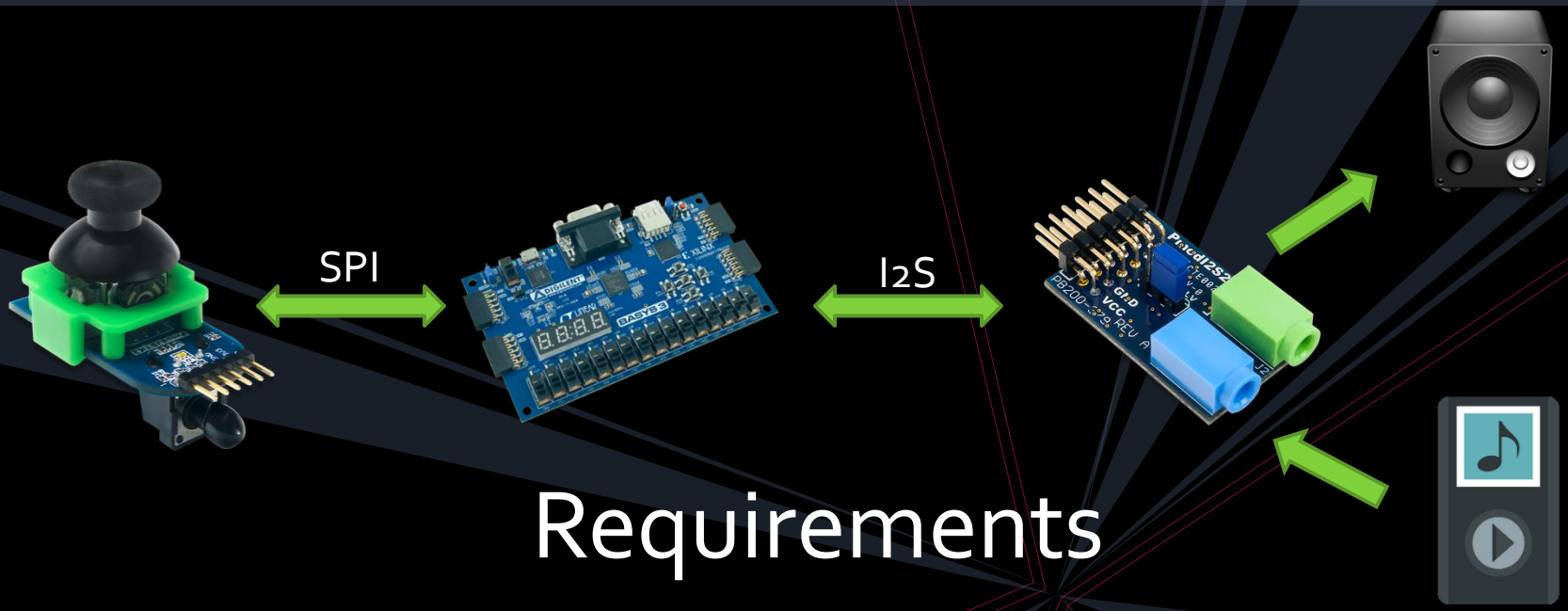


First step: loopback test





Back to Home assignment (1/4)



Requirements

The output audio should reproduce the input one with some "effects" applied:

- If no button is pressed, the vertical axis of the Joystick should control the volume of the output audio.
- If no button is pressed, the horizontal axis should control the audio balance.

Back to Home assignment (2/4)

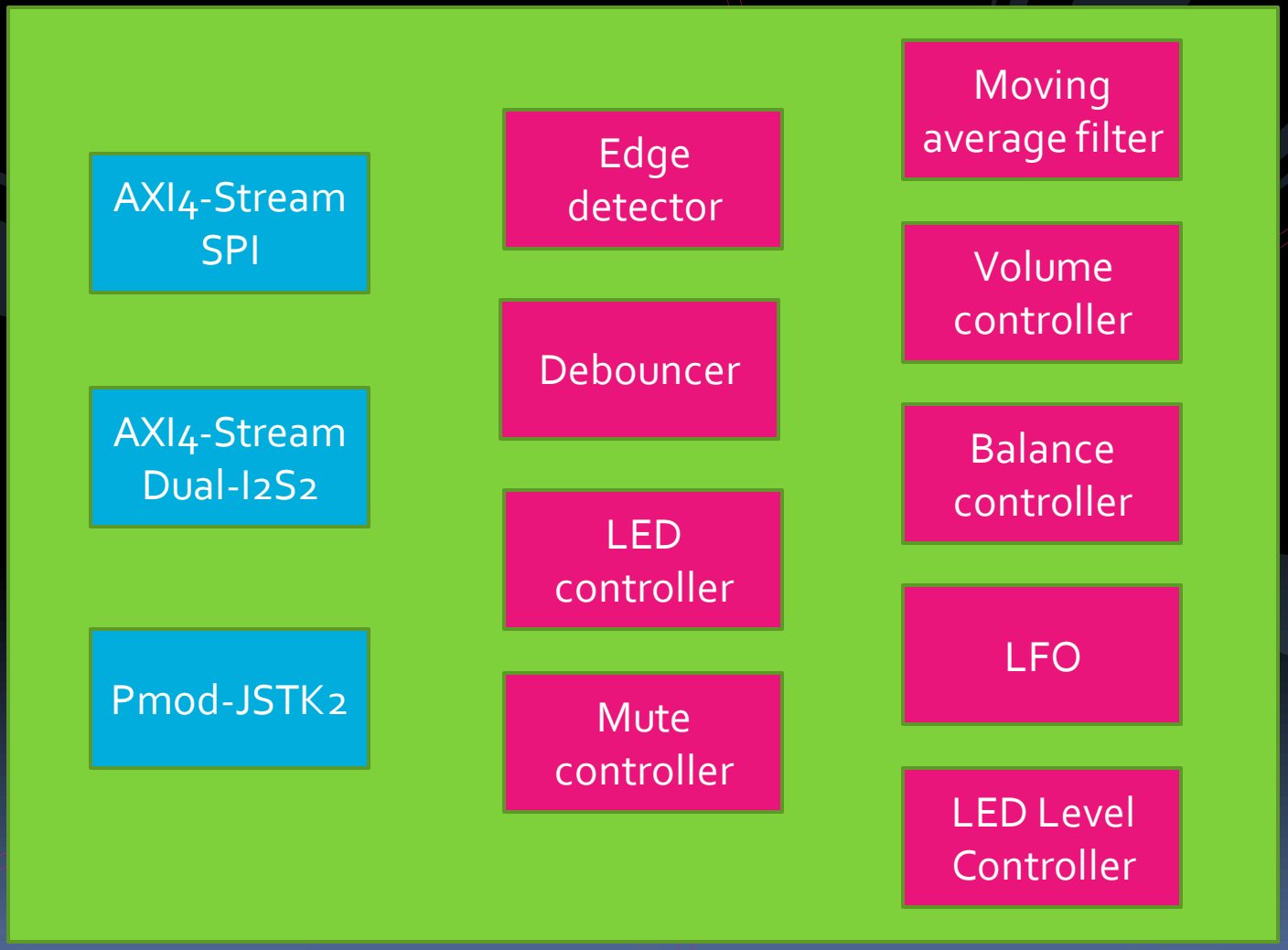
- If btnU is pressed the joystick vertical axis controls the LFO period.
- If btnU is pressed, moving the joystick horizontal axis has no effect.
- Turning SW0 on enables the LFO effect.
- The 16 LEDS of the Basys3 should turn on in a number proportional to the mean of the left and right audio sample

Back to Home assignment (3/4)

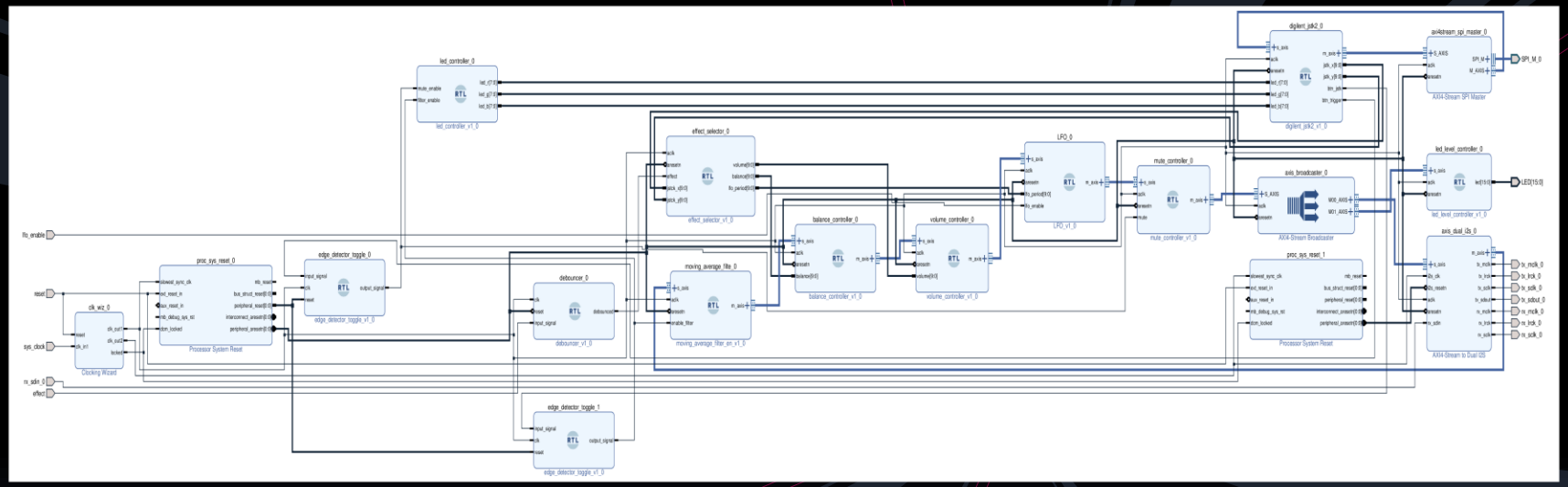
- Pushing* the "trigger button" mutes or unmutes the output channel.
- Pushing* the "joystick button" enables or disables a moving average filter (depth=32).
- The LED on the PmodJSTK2 module should show the status: muted (red), filter active (blue), no effects (green).

* toggles the status, not just "active when pressed"

Back to Home assignment (4/4)

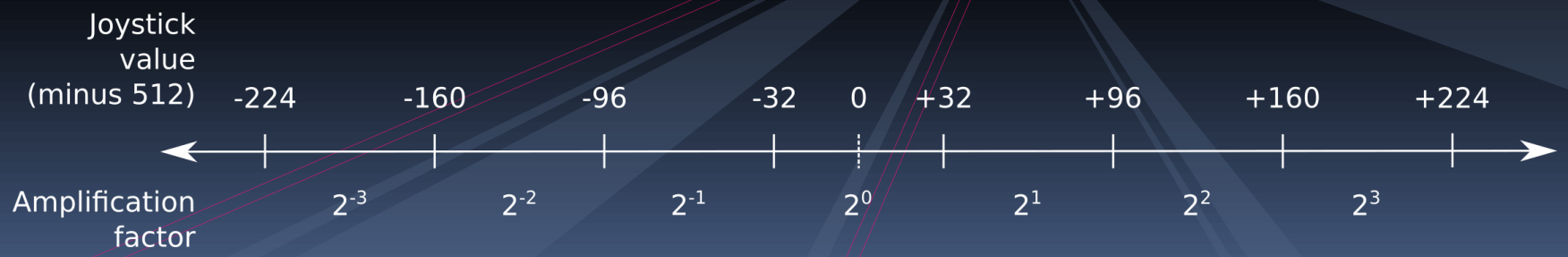


Block Design



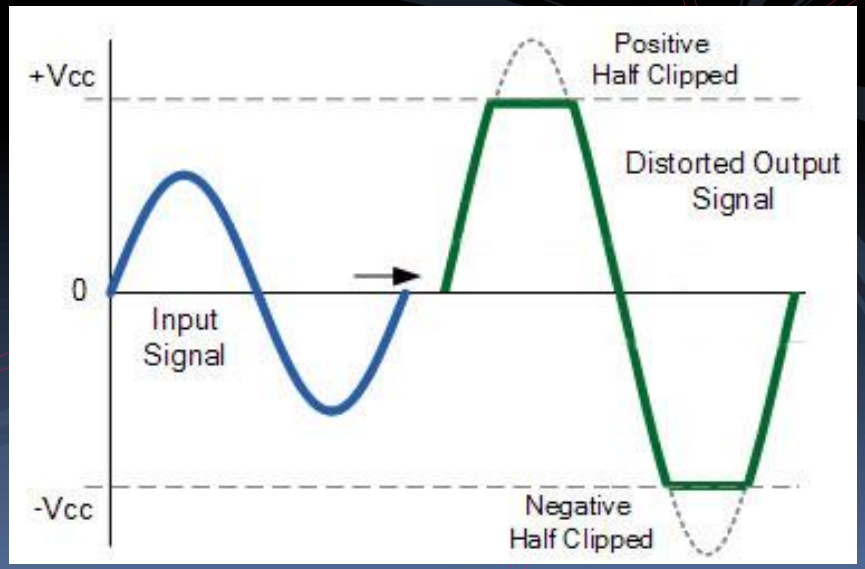
Details: volume (1/2)

We perceive "loudness" in a logarithmic way, so the volume control should be exponential. The amplification factor should double every 2^N "joystick units" (with the center in the half of the joystick dynamic, with N as generic). N=6 returns good results.



Details: volume (2/2)

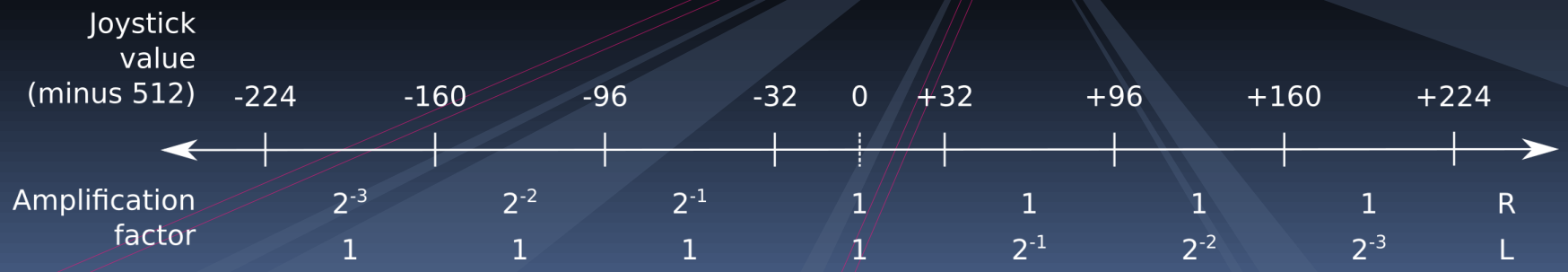
Be careful when multiplying: the signal must saturate at the maximum possible value ("clipping"), you must handle this manually to avoid unexpected results.



Details: balance control

Use an exponential amplification factor also for the balance control.

- Moving the joystick to the right decreases the left channel volume.
- Moving the joystick to the left decreases the right channel volume.



Details: mute

It is quite self explanatory

Details: moving average filter

The moving average module must be able to selectively apply a moving average filtering (of a fixed order of 32, set by generic) on the samples.

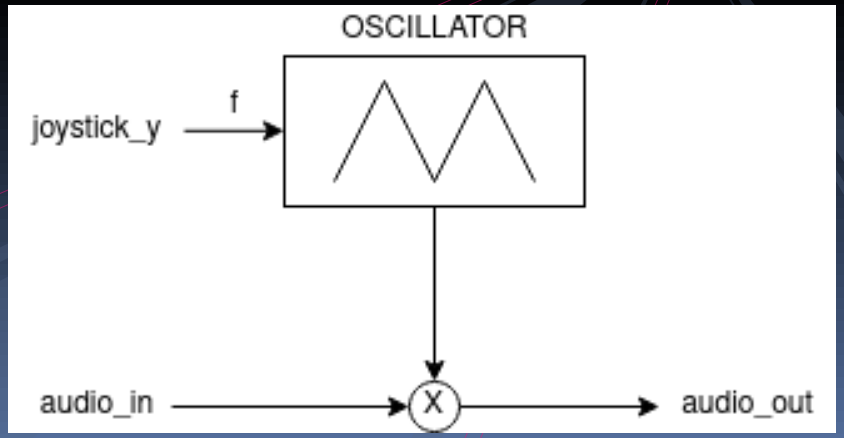
The module should filter the samples when “enable_filter” is high, and should simply pass the samples unmodified when “enable_filter” is low.

Details: LED controller

LED controller: sets the Pmod-JSTK2 LEDs to the correct colors, depending on its inputs ("mute_on" and "filter_on")

Details: LFO

The LFO (Low Frequency Oscillator) is a triangle-shape modulation on the volume of the incoming data, with its peak at 1 (meaning we don't have a boost on the volume) and minimum at 0. The frequency of the LFO can be speed up or slowed down by moving the y-axis of the Pmod-JSTK2, if btnU is pressed. The LFO effect is enabled with the switch SW0 of the Basys3 board.



Details: LFO

The LFO triangular (up and down) counter, which number of bit depends on the generic TRIANGULAR_COUNTER_LENGTH, has a base step dependent on the input according to the following formula:

LFO_Period := LFO_COUNTER_BASE_PERIOD - ADJUSTMENT_FACTOR*joystick_y

Where LFO_COUNTER_BASE_PERIOD and ADJUSTMENT_FACTOR are two constants.

Details: LED level controller

LED level controller: it turns on the 16 LEDs on the board, depending on the level of the audio at the output (right and left channels are averaged).