Experiment II: Sampling & Reconstruction on the NEXYS 2

Aims

In this laboratory section you will:

- Gain familiarity with the workings of an audio codec on the Nexys 2;
- Gain practical experience of the sampling and reconstruction of analogue signals, in particular you will characterise the anti-aliasing and reconstruction filters and observe the effects of aliasing;

Introduction

The Digilent Nexys 2 provides an FPGA-based **codec** and DSP system, where the functionality is implemented in VHDL, a **H**ardware **D**escription **L**anguage, rather than in conventional software. This implementation uses a **schematic** approach, so that the experimenter can see the structure of the DSP system graphically, then view and modify as necessary, the contents of the relevant modules in the system.

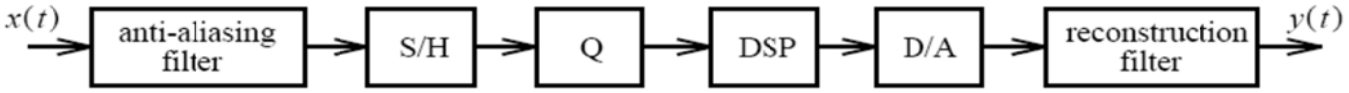

Figure 1: A block diagram of a practical DSP system.

Figure 1 shows a block diagram of a typical digital signal processing (DSP) system. On the Nexys 2 the ADC has a low pass filter with nominal cut-off frequency of around 500 kHz, however additional 10 kHz lowpass filters can be inserted at input and output. The Nexys 2 codec is implemented as separate analogue to digital (A2D) and digital to analogue (D2A) converters, these being represented by the sample and hold (S/H) plus quantiser (Q) and D/A blocks in Figure 1 respectively. Finally, the DSP block in Figure 1 is where the difference equation for implementing the desired digital filter is performed.

Equipment

PC with Xilinx ISE , Digilent Adept & Matlab;

1. PMOD AD1 and DA2 boards
2. 2 x PMOD CON4 boards
3. ADC and DAC Filter boards
4. Nexys 2 + JTAG interface cable/s;
5. Oscilloscope (preferably with FFT function);
6. 2 x cable: mono RCA male to mono BNC male, 0.5 - 1 metre long
7. Mono or stereo 3.5mm male to mono or stereo RCA male
8. Mono or stereo Y-adaptor, 3.5mm Male to 2 x 3.5mm Female
9. Signal Generator;
10. External speakers + audio jack cable + power pack;
11. 1 BNC T-adaptor M to 2F (F-M-F);
12. 1 x cable BNC Male to BNC Male, 0.5 - 1 metre long.

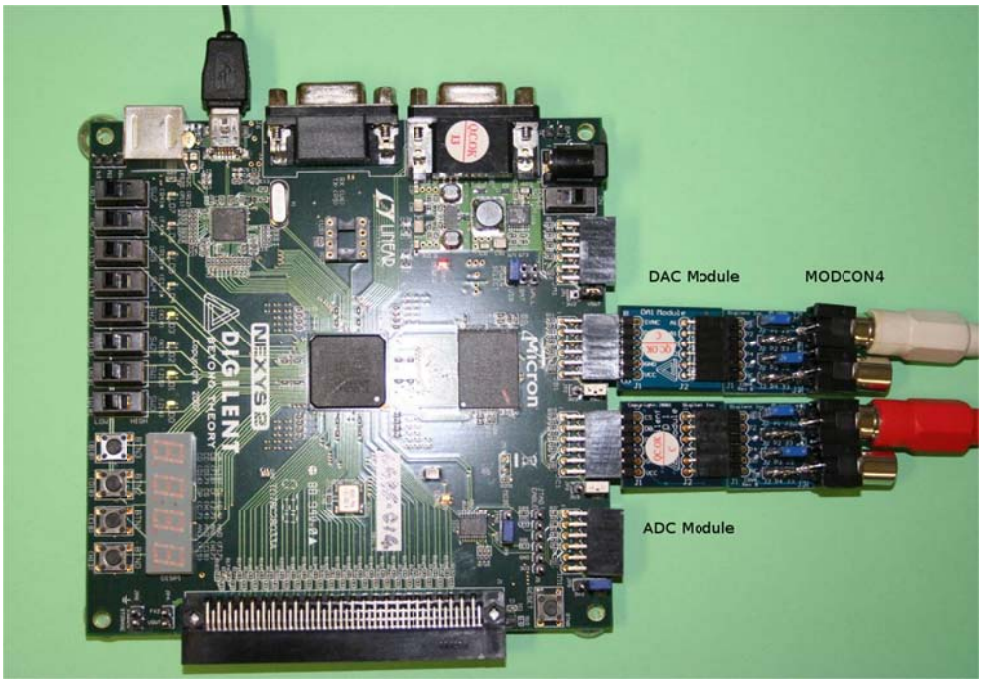

Figure 2. Nexys2 board with cable connections

Preparation

Note: preparation will be checked at the start of each laboratory class.

Answer the following questions:

1. Bearing in mind that the anti-aliasing filter on the PMOD-AD1 is set to approx. 500kHz, explain what happens to the analogue signal, x(t), after it has passed through this filter and is presented to the input of the A2D, when:
   - x(t) is a sinusoidal signal of frequency 10 kHz;
   - x(t) is a square wave (50% duty cycle) of fundamental frequency 4 kHz.

2. What is the Fourier series representation of a square wave and of a triangle wave?

3. If the DSP block in Figure 1 is assumed to have a sampling frequency of 25 kHz and performs the following difference equation: y[n] = x[n], (that is, the output of the A2D is copied directly to the input of the D2A) what is the frequency and approximate amplitude of the signal, y(t), observed at the **output** of the reconstruction filter, when:
   - x(t) is a sinusoidal signal of frequency 10 kHz;
   - x(t) is a sinusoidal signal of frequency 12.5 kHz;
   - x(t) is a sinusoidal signal of frequency 15 kHz;
   - x(t) is a square wave of fundamental frequency 4 kHz;

4. Assume a 2^{nd} order Sallen-Key lowpass filter with corner frequency (F_c) of 10 kHz is used for the anti-aliasing and reconstruction filters.
   - What is the expected attenuation at F_c?
   - What is the cutoff slope in dB/octave and dB/decade?