Fundamentals of discrete-time signals and systems

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Required equipment:

- PC with Netbeans 8.2 & MATLAB installed
- Raspberry Pi
- Oscilloscope Agilent 54622D
- Signal generator Agilent 33120A
- Cables

1 Practical part

Practical part of the work consists of several tasks that should be performed on the Raspberry and some MATLAB simulations. It includes:

1. Frequency response of the embedded digital system.
2. Build-in ADC(DAC).
3. Aliasing and quantization effects.

Experiment 1
The RPi output noise measurement

1. Start Netbeans and load the project. Build the program and run it.
2. Connect the output of the RPi board to the input of the oscilloscope.
3. On the oscilloscope press **Edge** button and set the triggering to the channel that corresponds to the output signal from the signal generator. Compress the horizontal axes to 200ms per division.
4. Press \texttt{Quick meas} and set \texttt{Source} to the channel that corresponds to the output from the RPi. By pressing corresponding soft key measure the RMS value of the RPi output signal. If the obtained value still significantly varies, try to obtain better estimate by compressing the horizontal axis a bit more. Under the assumption that the additive noise is a zero-mean process, the obtained value equals the estimated standard deviation $\sigma_n$ of the additive noise present at the output of the RPi and induced by the connecting cables.

5. Assume the maximum allowed output amplitude to be 1Vpp. Based on the RPi noise level calculate how many bits out of 16 are then masked by the noise.

**Experiment 2**

Measuring the RPi antialiasing filter frequency response.

1. In Netbenas, open and load project file and rebuild it.

2. Connect the output of the signal generator to the input channel of the RPi.

3. On signal generator set the waveform to a sinusoid by pressing $\sim$ key. Set the input frequency to 100Hz and amplitude to 500mVpp (assuming the signal generator was set up for the input with the high impedance). Press \texttt{Freq} again.

4. Run the program.

5. Make sure that the oscilloscope uses the external trigger. To check it, press \texttt{Edge} button in the trigger section of oscilloscope controls. On the oscilloscope display the check mark should be at \texttt{Ext}.

6. Switch off the oscilloscope input channel that corresponds to the signal generator. Press \texttt{Math} button and choose \texttt{FFT}, then \texttt{Settings}. Set \texttt{Source} to the channel that corresponds to the input for the RPi, \texttt{Span}=20kHz, and \texttt{Center}=10kHz. You should see one peak at 100Hz. To make sure that the peak appears exactly at 100Hz use cursors. Press \texttt{Cursors} and set \texttt{Source} =”Math”. Press \texttt{X1} or \texttt{X2} soft key and turn $\circ$ knob to adjust the cursors. Press \texttt{X Y} soft key to change cursors to Y-axis and set up \texttt{Y1} to the noise level around the peak.

7. By increasing the frequency of the sinusoid from 100Hz, find the frequency at which the amplitude of the peak goes under the noise floor. This value stands for the highest harmonic that passes through the RPi.

8. Set up the signal generator to produce a sweep between 50Hz and the frequency you estimated in the previous task + some extra bandwidth (just try several different values (on the order of kHz) to obtain a good visual result). By changing the vertical position of a waveform on the oscilloscope, place a ground marker at the bottom of the screen to make only half of the waveform visible.

9. Sketch ”end-to-end” frequency response from the analog input to the analog output of the RPi.
10. Determine the following values: width of the passband region $W_{\text{pass}}$ [Hz] (measured as part of the filter’s frequency response that lies within 3dB from the maximum response), maximum passband gain $G_{\text{pass}}^{\text{max}}$ [dB], and roll-off rate $R_{\text{roff}}$ [dB/Hz]. Note, that the frequency response you see on the oscilloscope’s screen is not in dB scale and the time axis also has to be converted into frequency scale (according to the start and stop sweep frequencies set on the signal generator). Make sure you re-label the axes properly before computing the values.