Lab Class 8
02.12.2021

- **Low-Pass Filter.**

Theoretical part: Design of a first-order low-pass filter via bilinear transform

Time allowed: 45'.

1. starting from the Fourier transform of a real system's response function $\tilde{H}(\omega) = \frac{1}{1-i\omega\tau}$, derive the z-transform of the simulator's response function $V(z)$;
2. write the difference equation and draw a block diagram of the simulator;
3. by placing the pole at $1 - 2^{-k}$, $k \in \mathbb{N}^+$ and assuming $T \ll \tau$, derive the approximate dependency of the cutoff frequency $f_{3\,\mathrm{dB}} = (2\pi\tau)^{-1}$ on the parameter k and the sampling frequency $f_s = 1/T$;
4. predict the frequency behaviour via "backward interpretation of the simulation theorem".

Preliminary Operations

1. **set the waveform generator so that the output voltage has an offset value of approximately 1.65 V and an amplitude of 1 V; check the result by using the oscilloscope**;
2. connect the BNC cables **(avoid connecting the generator to the DAC output!)**;
3. upload on the board via impact the executable file "lowPassFilter.template.bit";
4. connect the DAC A and DAC B output to the channel 1 (X) and 2 (Y) of the oscilloscope, respectively;

5. by
   - using the switches to set the cutoff frequency and
   - changing the input frequency,

   observe the result.

Problems

1. Implementation of a low-pass filter, as follows:
   - implement a first-order (roll-off: -6 dB/octave) low-pass filter (LPF) whose cutoff frequency f_{3dB} is settable via the switches;
   - **for the sake of simplicity it is allowed to replace $x[n]+x[n-1]$ with $2x[n]$** (this operation does not change the low-frequency behaviour of the filter);
   - determine the Bode diagram of gain and phase for a single value of f_{3dB} preferably corresponding to $k = 4$).

   The final result should look like the system corresponding to the executable file *lowPassFilter.template.bit*.

At the end, show the result to the lecturer.

Upon eliminating the unuseful files (only *.v*, *.ucf*, *.xise* are necessary), compress the working folder via
`tar czf labClass_8_<names>.tgz <Folder>`
and upload the compressed file to the Moodle platform.

Please note that the folder, and thus the compressed file, should also include the Bode diagrams.

Additional problems

- Implementation of a sinusoidal oscillator by filtering – possibly with multiple LPFs in cascade – a square waveform.
- Implementation of a notch filter.
- Implementation of a phase-shifter (see Fig. 1 for the analog implementation to simulate).

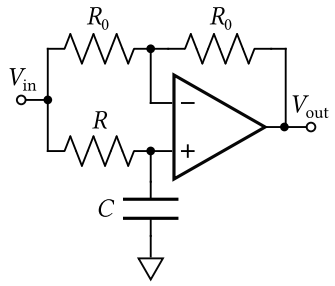

Figure 1: Analog phase-shifter.

Upon eliminating the unuseful files (only *.v*, *.ucf*, *.xise* are necessary), compress the working folder via
`tar czf labClass_8_<names>_additional.tgz <Folder>`
and upload the compressed file to the Moodle platform.

At the first favorable circumstance, show the result to the lecturer.