DSP Lab 07: Checking properties of discrete systems in Simulink

1. Objective

Students should create and use discrete systems in the Simulink environment, and know how to check their linearity and time invariance properties

2. Theoretical aspects

Properties of discrete systems

Two fundamental properties of discrete systems:

- Linearity:

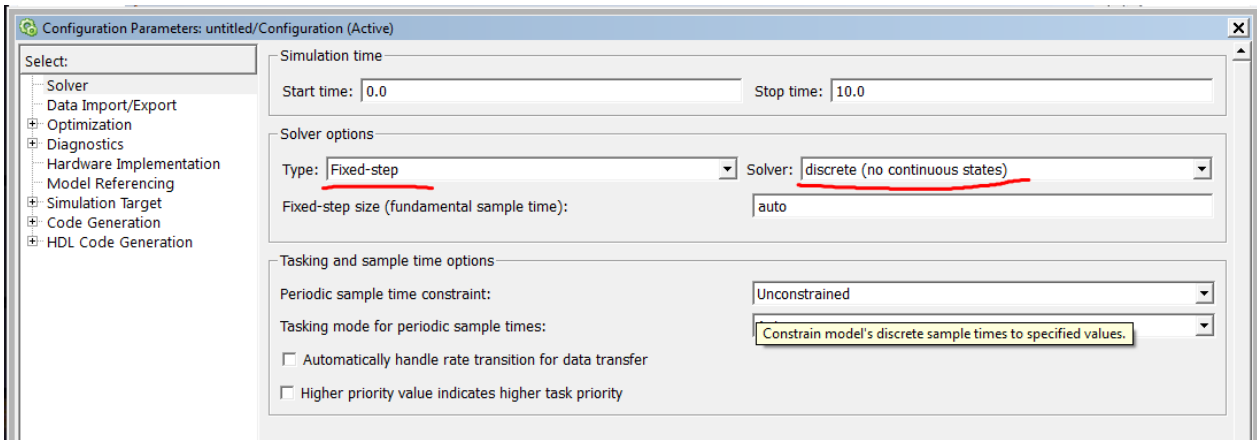
$$H\{a \cdot x_1[n] + b \cdot x_2[n]\} = a \cdot H\{x_1[n]\} + b \cdot H\{x_2[n]\}$$

- Time Invariance:

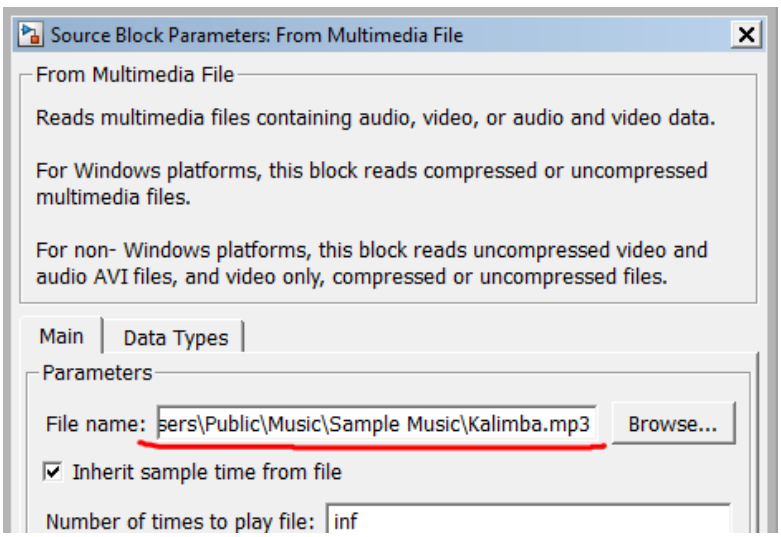
$$H\{x[n-k]\} = y[n-k], \text{ where } y[n] = H\{x[n]\}$$

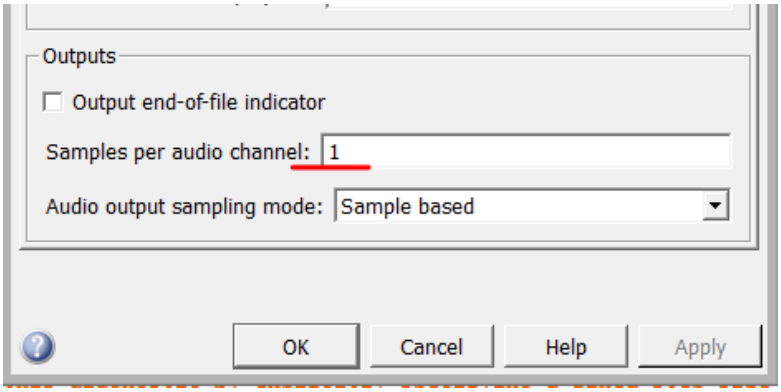
Required Simulink Settings

Settings needed for discrete models and simulation. Open menu Simulation -> Model Configuration Parameters and set the options as shown below.



Special settings needed for the *From Multimedia Device* block are shown below.





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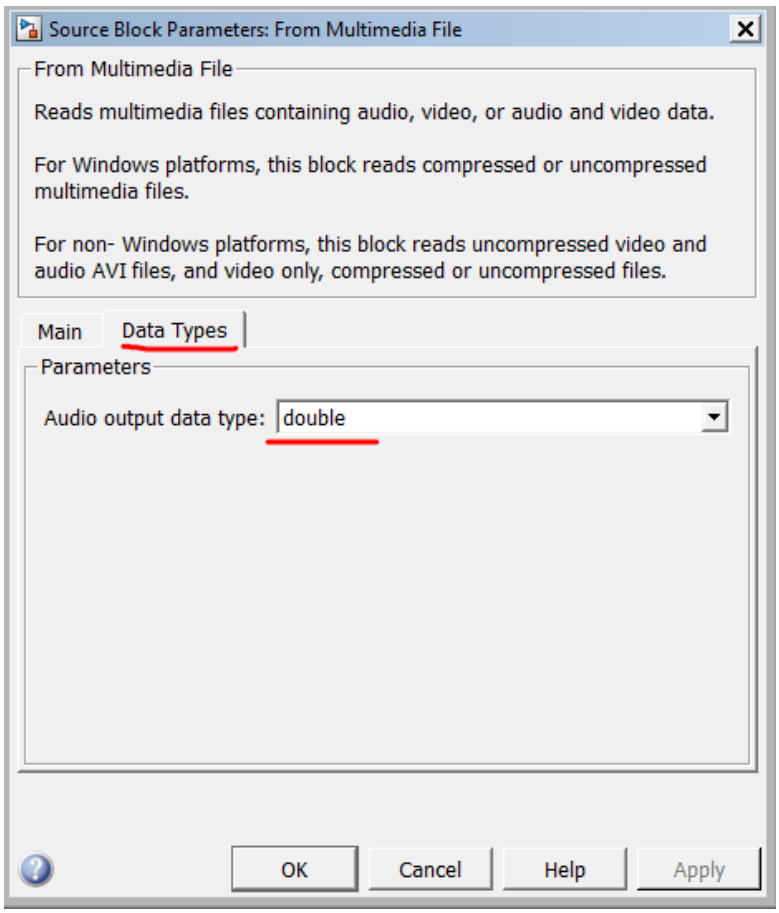

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Basic Simulink blocks for digital signal processing

Advanced Multimedia blocks from the DSP Toolbox: FromMultimediaFile, AudioDeviceWriter, Buffer

Saving data to/from Matlab environment: ToWorkspace, FromWorkspace

3. Exercises

1. Create a Simulink model to implement the following system H_1:
$$y[n] = H_1\{x[n]\} = 0.8y[n-1] + 0.25x[n] + 0.1x[n-1]$$
   - the system should be implemented as a Subsystem block with one input and one output signal
2. Try to guess what type of filter this is, low-pass or high-pass, by putting some signal at the input and looking at the output.
3. Test linearity of this system by checking if the linearity equation holds
   - create multiple copies of the system inside the model (copy/paste)
   - use two randomly generated input vectors `x` and `y` (use one of the *Random* blocks), and some two constants `a` and `b`
   - check that the output of the system when the input is `a*x + b*y` is exactly equal to the weighted sum of the outputs applied separately to `x` and `y`
4. Test time-invariance in a similar way
   - the system will be applied to an input vector `x` , and to `x` prepended with a variable number of zeros (i.e. time delayed)
   - the outputs shall be checked if they verify the time invariance equation
5. Find an input signal $x[n]$ to show that the system $y[n] = y[n-1] + x[n]$ is unstable. Show it by simulating the model and displaying the output.

1. Implement and apply the following system to the audio data (mp3 file) loaded with FromMultimediaFile and play the resulting output (ToAudioSink). How is the sound affected?
$$y[n] = \frac{1}{5} \cdot (-0.7y[n-1] + x[n] + 0.5x[n-1])$$
   Make sure you set the properties of the *From Multimedia File* block as shown above
2. Change the system to the following and check how it sounds:
$$y[n] = \frac{1.7}{0.5} \cdot (0.7y[n-1] + x[n] - 0.5x[n-1])$$
3. Test the linearity and the time invariance for two other systems as well:
   - $y[n] = (x[n])^2 + 0.1x[n] + \sqrt{x[n]})$
   - $y[n] = n \cdot x[n] + x[n-1]$

4. Final questions

1. TBD