Digital Signal Processing

EE3900: Linear Systems and Signal Processing

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1. Software Installation

Install the necessary packages by running the following commands

```
sudo dnf up
sudo dnf install libffi−dev libsndfile1 python3−
    scipy python3−numpy python3−matplotlib
pip install cffi pysoundfile
```

2. Digital Filter

2.1 Download the sound file from

```
wget https://github.com/Dhatrireddyy/EE3900/
    blob/main/Sound_Noise.wav
```

2.2 You will find a spectrogram at https://academo.org/demos/spectrum-analyzer. Upload the sound file that you downloaded in Problem **??** in the spectrogram and play. Observe the spectrogram. What do you find?
Solution: There is a lot of background noise and the key strokes are audible. This noise is represented by the large blue and red regions spread from 440 Hz to beyond 18.9 kHz. The key tones are represented by the yellow lines that are present in the lower regions between 440 Hz and 5.1 kHz.

2.3 Write the python code for removal of out of band noise and execute the code.
Solution: Download the python code for the reduction of noise by executing the following command

```
wget https://github.com/Dhatrireddyy/EE3900/
    blob/main/codes/2.3.py
```

Run the code by executing

```
python3 2.3.py
```

2.4 The output of the python script in Problem 2.3 is the audio file Sound_With_Reduced_Noise.wav. Play the file in the spectrogram in Problem 2.2. What do you observe? **Solution:** The noise has been reduced considerably and the key strokes are not audible anymore. The blue region is restricted between 440 Hz and 5.1 kHz and there are no signals beyond this range.

3. Difference Equation

3.1 Let

$$x(n) = \left\{\underset{\uparrow}{1}, 2, 3, 4, 2, 1\right\} \tag{3.1}$$

Sketch $x(n)$

3.2 Let

$$y(n) + \frac{1}{2}y(n-1) = x(n) + x(n-2), \quad y(n) = 0, n < 0 \tag{3.2}$$

Sketch $y(n)$
Solution: Download the following Python code that plots Fig. 3.2.

```
wget https://github.com/Dhatrireddyy/EE3900/
    blob/main/codes/3.2.py
```

Run the code by executing

```
python3 3.2.py
```

4. Z-transform

4.1 The Z-transform of $x(n)$ is defined as

$$X(z) = \mathcal{Z}\{x(n)\} = \sum_{n=-\infty}^{\infty} x(n)z^{-n} \tag{4.1}$$

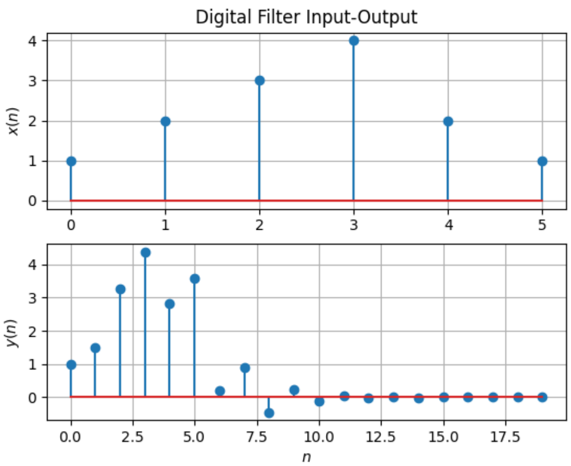

Fig. 3.2. The sketches of $x(n)$ and $y(n)$

Show that

$$\mathcal{Z}\{x(n-1)\} = z^{-1}X(z) \tag{4.2}$$

and find

$$\mathcal{Z}\{x(n-k)\} \tag{4.3}$$

Solution:

$$\mathcal{Z}\{x(n-1)\} = \sum_{n=-\infty}^{\infty} x(n-1)\, z^{-n} \tag{4.4}$$

Substitute $n - 1 = p$

$$\mathcal{Z}\{x(n-1)\} = \sum_{p=-\infty}^{\infty} x(p) z^{-(p+1)} \tag{4.5}$$

$$= z^{-1} \sum_{m=-\infty}^{\infty} x(p) z^{-p} \tag{4.6}$$

$$= z^{-1}\mathcal{Z}\{x(m)\} \tag{4.7}$$

$$= z^{-1}X(z) \tag{4.8}$$

$$\mathcal{Z}\{x(n-k)\} = \sum_{n=-\infty}^{\infty} x(n-k) z^{-n} \tag{4.9}$$

$$= \sum_{m=-\infty}^{\infty} x(p) z^{-(p+k)} \tag{4.10}$$

$$= z^{-k} \sum_{m=-\infty}^{\infty} x(p) z^{-p} \tag{4.11}$$

$$= z^{-k}X(z) \tag{4.12}$$