EE 511 - Homework 01

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Part 1: Signal with no harmonics

1a) Draw the following waveform:

$$\begin{cases} 6sin(\omega t+\pi/3) & t<0.1 \\ 10sin(\omega t+\pi/3) & t\geq 0.1 \end{cases}$$

Given that, $f = 60$ Hz, and sampling frequency is 12 samples per cycle.

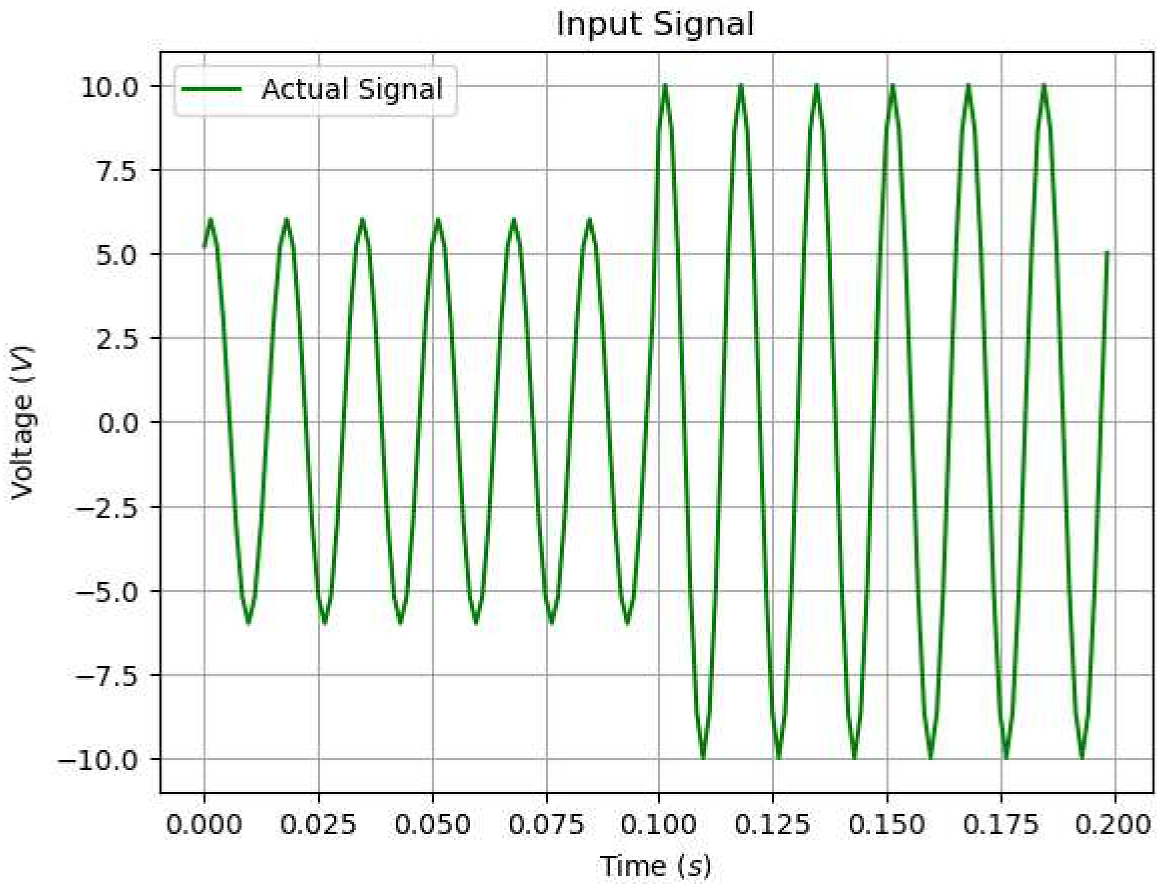
In [1]:
```
## IMPORT PACKAGES
import matplotlib.pyplot as plt
import numpy as np
import math
```

In [2]:
```
## PARAMETER INPUT
f = 60.0             # frequency in Hz
T = 1/f              # period in seconds
n = 12               # samples per cycle
dT  = T/n            # delta T
A1  = 6.0            # amplitude of first signal
A2  = 10.0           # amplitude of second signal
A3  = 3.0            # amplitude of second harmonic
w = 2 * np.pi * f    # omega
StartTime = 0
EndTime = 0.2
```

Plotting the input signal:

In [3]:
```
## PLOTTING INPUT SIGNAL
Time = np.arange(StartTime,EndTime,dT)
Voltage1 = []

for t in range(0,len(Time)):

    if Time[t] < 0.1:
        v = A1 * np.sin(w * Time[t] + np.pi/3) # first signal
    else:
        v = A2 * np.sin(w * Time[t] + np.pi/3) # second signal

    Voltage1.append(v)

plt.plot(Time,Voltage1,'green')
plt.title("Input Signal")
plt.xlabel("Time $(s)$")
plt.ylabel("Voltage $(V)$")
plt.legend(["Actual Signal"])
```

```
plt.grid()
plt.show()
```



1b) Estimate the amplitude of the signal using Mann&Morrison algorithm

In Mann & Morrison algorithm, it is assumed that the signal can be represented as a pure sinusoid whose amplitude as well as frequency is constant during the period under consideration [1].

So for a signal $V = V_p sin(\omega_0 t + \theta)$:

$$V_p = \sqrt{(V_p sin\theta)^2 + (V_p cos\theta)^2} = \sqrt{(V_0)^2 + (\frac{V_{+1} - V_{-1}}{2\omega_0 \Delta t})^2}$$

Here, sine component, $V_p sin\theta = V_0$ and cosine component $V_p cos\theta = \frac{V_{+1} - V_{-1}}{2\omega_0 \Delta t}$

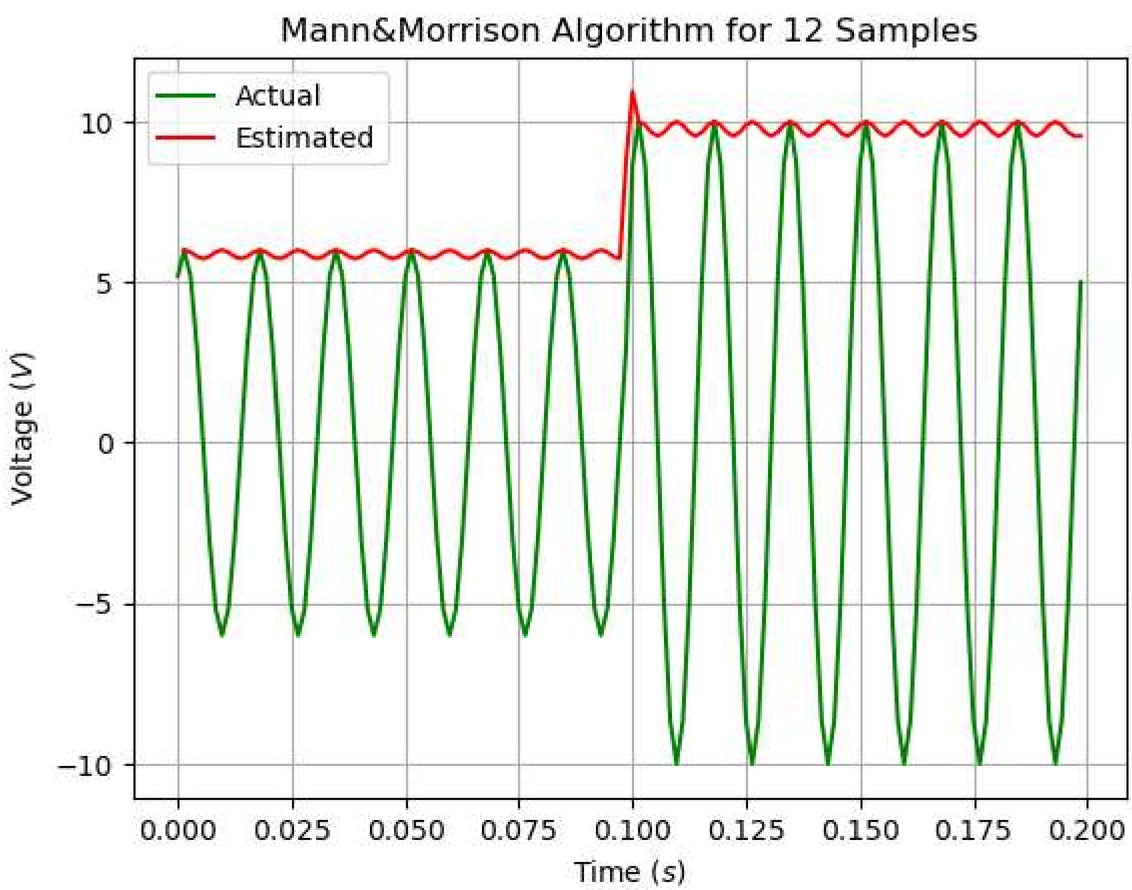
Mann & Morrison Algorithm Function:

In [4]:
```
# MANN & MORRISON ALGORITHM

def MannMorrison(StartTime,EndTime,sample,frequency,voltage):

    f0 = frequency # fundamental frequency
    n = sample

    T = 1/f0
    dT = T/n
    w0 = 2 * np.pi * f0
    time = np.arange(StartTime,EndTime,dT)
```

```
    Vp = []

    for t in range(1, len(time)-1):
        sine_component = voltage[t]
        cosine_component = (voltage[t+1] - voltage[t-1])/(2 * w0 * dT)
        vp_temp = np.sqrt(sine_component**2 + cosine_component**2)
        Vp.append(vp_temp)

    Vp.append(vp_temp)

    # PLOT
    plt.plot(time,voltage,'green')
    plt.plot(time[1:len(time)],Vp,'r-')
    plt.title("Mann&Morrison Algorithm for " + str(n) + " Samples")
    plt.xlabel("Time $(s)$")
    plt.ylabel("Voltage $(V)$")
    plt.legend(["Actual", "Estimated"])
    plt.grid()
    plt.show()
```

Applying Mann & Morrison algorithm on input signal:

In [5]:
```
MannMorrison(StartTime,EndTime,n,f,Voltage1)
```



1c) Estimate the amplitude of the signal using Prodar algorithm

The basic difference between Mann&Morrison and Prodar algorithm is, in Prodar algorithm, the sine component is taken from second derivative [1]. In this way, if there is a DC component in the input signal it can be handled.

So for a signal $V = V_p sin(\omega_0 t + \theta)$:

$$V_p = \sqrt{(V_p sin\theta)^2 + (V_p cos\theta)^2}$$

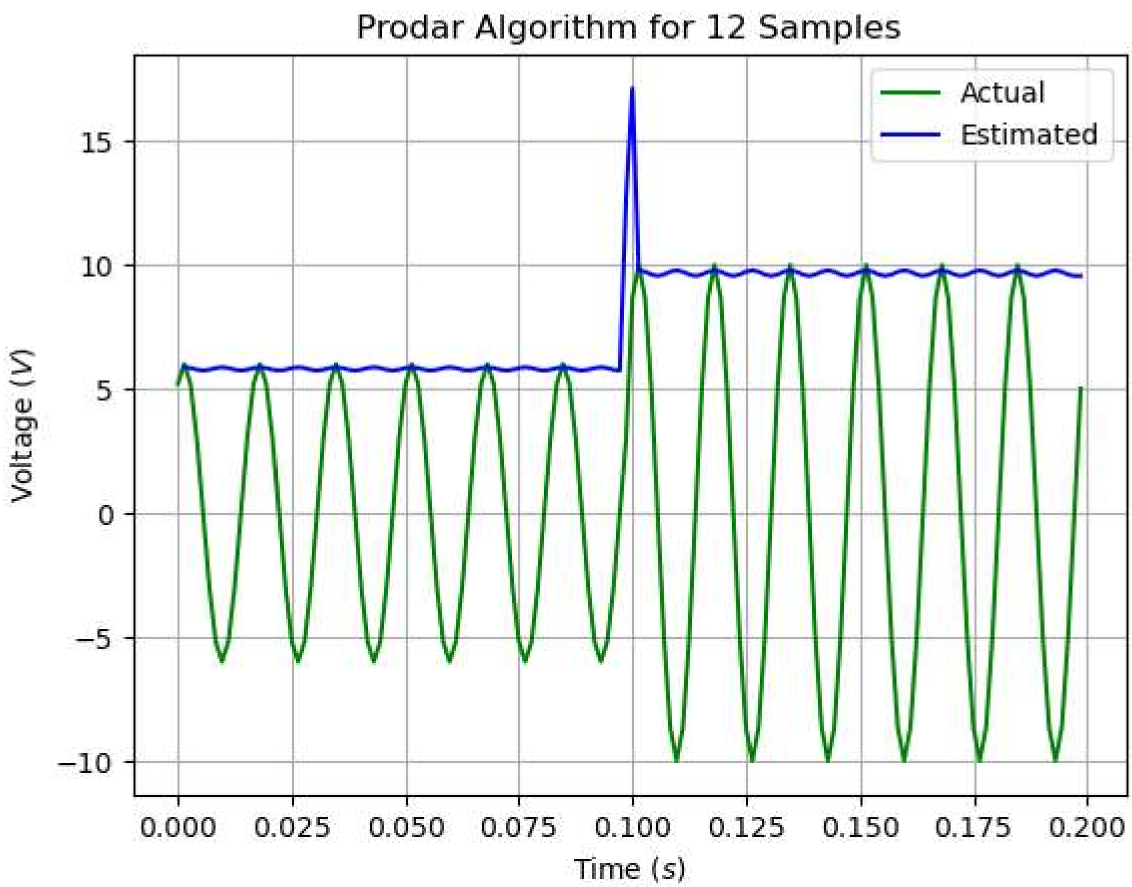
Where, sine component, $V_p sin\theta = \frac{V_{+1} - 2V_0 + V_{-1}}{(\omega_0 \Delta t)^2}$ and cosine component $V_p cos\theta = \frac{V_{+1} - V_{-1}}{2\omega_0 \Delta t}$

Prodar Algorithm Function:

In [6]:
```
# PRODAR ALGORITHM

def Prodar(StartTime,EndTime,sample,frequency,voltage):

    f0 = frequency # fundamental frequency
    n = sample

    T = 1/f0
    dT = T/n
    w0 = 2 * np.pi * f0
    time = np.arange(StartTime,EndTime,dT)
    Vp = []

    for t in range(1, len(time)-1):
        sine_component = (voltage[t+1] - 2 * voltage[t] + voltage[t-1])/((w0 * dT)**2)
        cosine_component = (voltage[t+1] - voltage[t-1])/(2 * w0 * dT)
        vp_temp = np.sqrt(sine_component**2 + cosine_component**2)
        Vp.append(vp_temp)

    Vp.append(vp_temp)

    # PLOT
    plt.plot(time,voltage,'green')
    plt.plot(time[1:len(time)],Vp,'b-')
    plt.title("Prodar Algorithm for " + str(n) + " Samples")
    plt.xlabel("Time $(s)$")
    plt.ylabel("Voltage $(V)$")
    plt.legend(["Actual", "Estimated"])
    plt.grid()
    plt.show()
```

Applying Prodar algorithm on input signal:

In [7]:
```
Prodar(StartTime,EndTime,n,f,Voltage1)
```



Part 2: Signal with harmonics

2a) Add second harmonic to the signal which means the signal becomes as follows:

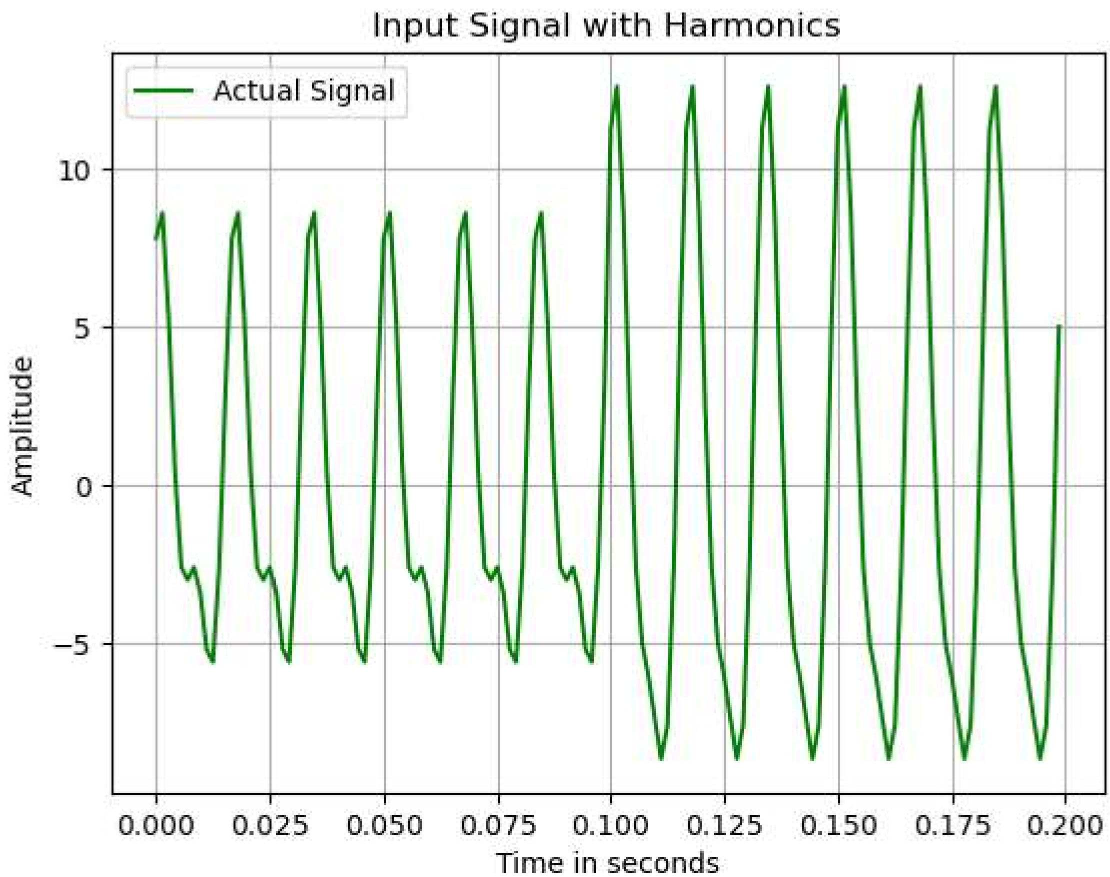
$$\begin{cases} 6sin(\omega t + \pi/3) + 3sin(2\omega t + \pi/3) & t < 0.1 \\ 10sin(\omega t + \pi/3) + 3sin(2\omega t + \pi/3) & t \geq 0.1 \end{cases}$$

Given that, $f = 60$ Hz, and sampling frequency is 12 samples per cycle.

Plotting the input signal:

In [8]:
```
## PLOT
Time = np.arange(StartTime,EndTime,dT)
Voltage2 = []

for t in range(0,len(Time)):

    if Time[t] < 0.1:
        v = (A1 * math.sin(2 * np.pi * f * Time[t] + np.pi/3)) +
        (A3 * math.sin(2 * 2 * np.pi * f * Time[t] + np.pi/3)) # First signal
    else:
        v = A2 * math.sin(2 * np.pi * f * Time[t] + np.pi/3) +
        (A3 * math.sin(2 * 2 * np.pi * f * Time[t] + np.pi/3)) # Second signal

    Voltage2.append(v)

plt.plot(Time,Voltage2,'green')
```

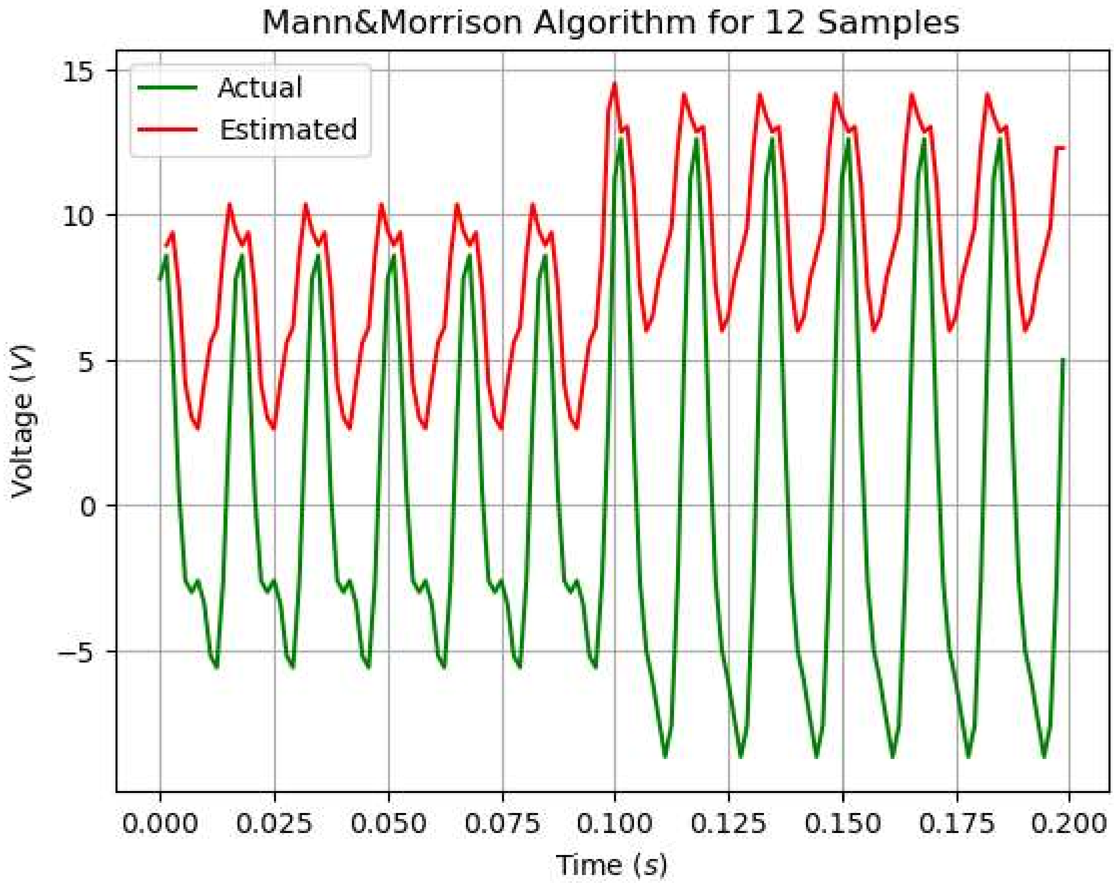
```
plt.title("Input Signal with Harmonics")
plt.xlabel("Time in seconds")
plt.ylabel("Amplitude")
plt.legend(["Actual Signal"])
plt.grid()
plt.show()
```



2b) Estimate the amplitude of the signal using Mann&Morrison algorithm

Applying Mann & Morrison algorithm on input signal:

In [9]:
```
# MANN & MORRISON ALGORITHM
MannMorrison(StartTime,EndTime,n,f,Voltage2)
```

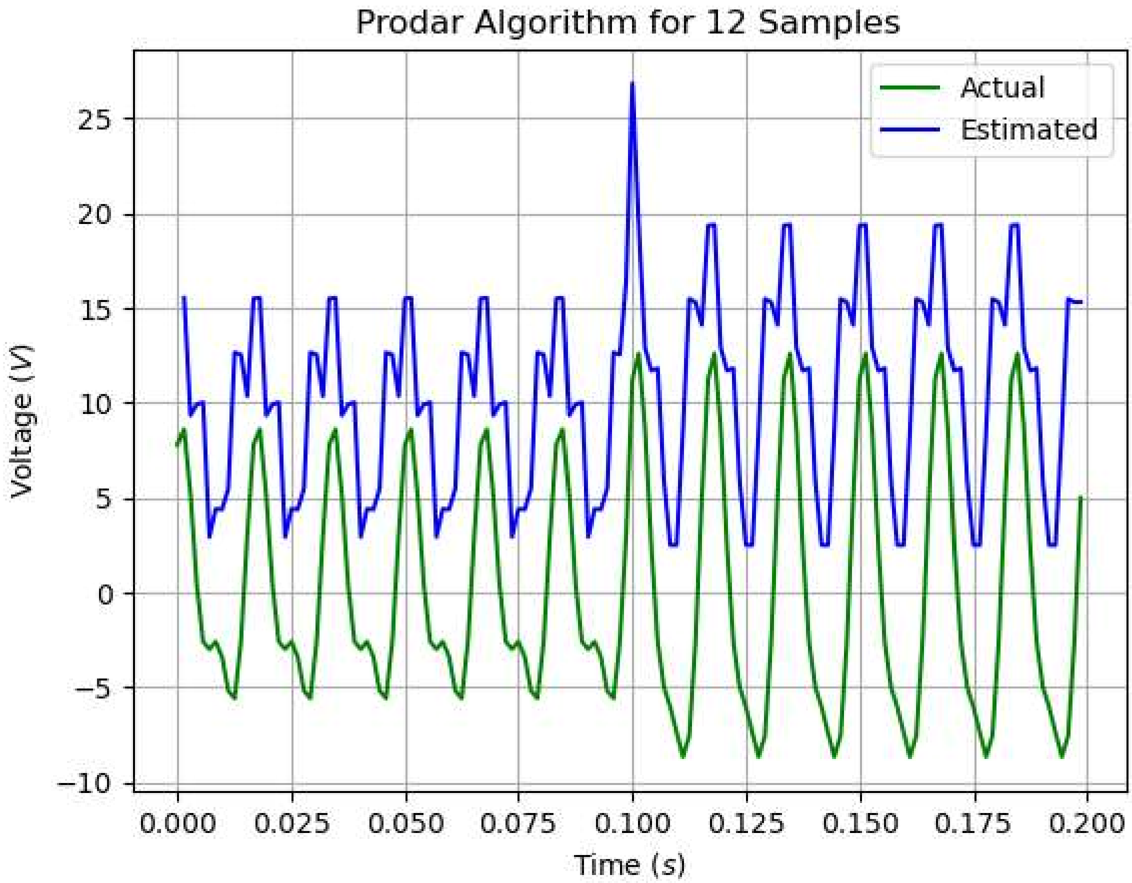


2c) Estimate the amplitude of the signal using Prodar algorithm

Applying Prodar algorithm on input signal:

In [10]:

```
Prodar(StartTime,EndTime,n,f,Voltage2)
```



References

[1] S. R. Bhide, *Digital Power System Protection*, Delhi, 2014.

Source Code

GitHub Link for this Jupyter Notebook: EE511_WSU_Homework1