Upsampling of 1000 Hz Sine

Display of sinusoidal waveform using a stem plot. Upsampling by insertion of zeros and interpolation using a sinc function.

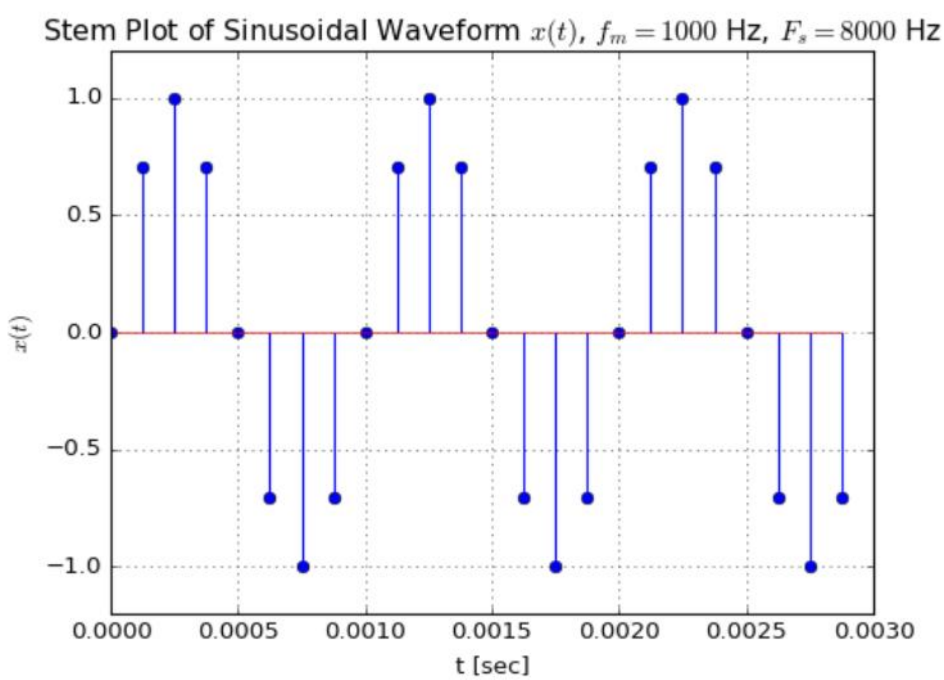
In [1]:
```
import numpy as np
import matplotlib.pyplot as plt
```

In [2]:
```
%matplotlib notebook
fsz = (7,5)  # figure size
fsz2 = (fsz[0],fsz[1]/2.0)  # half high figure
```

In [3]:
```
# initial parameters
Fs = 8000   # sampling rate
fm = 1000   # frequency of sinusoid
tlen = 1.0  # length in seconds
```

In [4]:
```
# generate time axis
tt = np.arange(np.round(tlen*Fs))/float(Fs)
# generate sine
xt = np.sin(2*np.pi*fm*tt)
```

In [5]:
```
# make stem plot
plt.figure(1, figsize=fsz)
plt.stem(tt[:24], xt[:24])
plt.ylim([-1.2, 1.2])
plt.ylabel('$x(t)$')
plt.xlabel('t [sec]')
strt1 = 'Stem Plot of Sinusoidal Waveform $x(t)$'
strt1 = strt1 + ', $f_m={}$ Hz, $F_s={}$ Hz'.format(fm, Fs)
plt.title(strt1)
plt.grid()
plt.savefig('sine1000_Fs8000.eps')
```

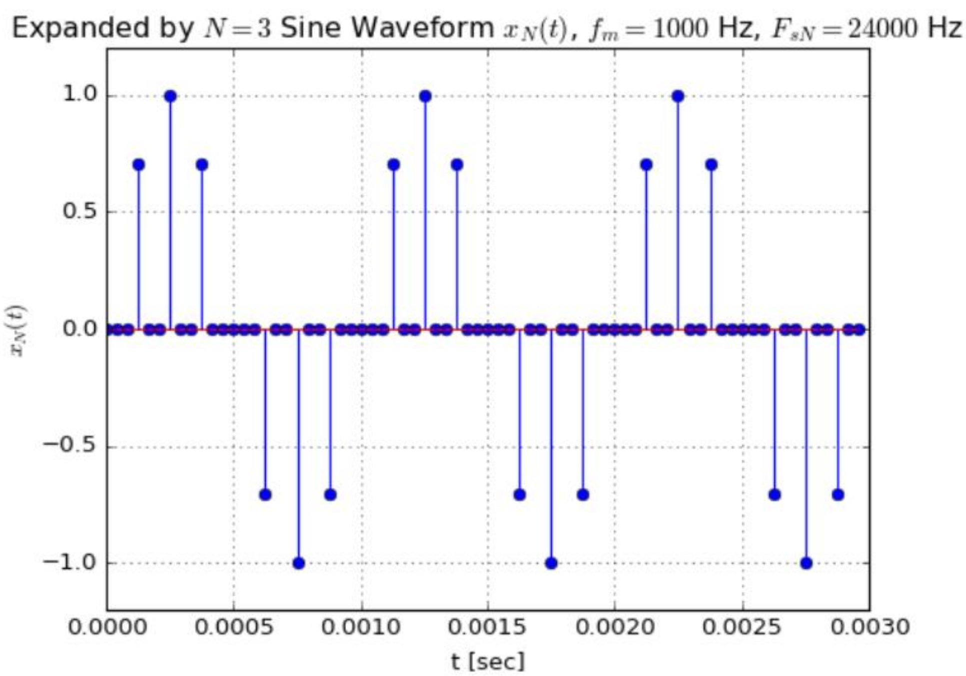


In [6]:
```
N = 3   # upsampling factor
xNt = np.vstack((xt, np.zeros((N-1, xt.size))))  # expand N times
xNt = np.reshape(xNt, -1, order='F')   # reshape into array
print(xNt[:24])   # check readout order
```

```
[  0.00000000e+00   0.00000000e+00   0.00000000e+00   7.07106781e-01
   0.00000000e+00   0.00000000e+00   1.00000000e+00   0.00000000e+00
   0.00000000e+00   7.07106781e-01   0.00000000e+00   0.00000000e+00
   1.22464680e-16   0.00000000e+00   0.00000000e+00  -7.07106781e-01
   0.00000000e+00   0.00000000e+00  -1.00000000e+00   0.00000000e+00
   0.00000000e+00  -7.07106781e-01   0.00000000e+00   0.00000000e+00]
```

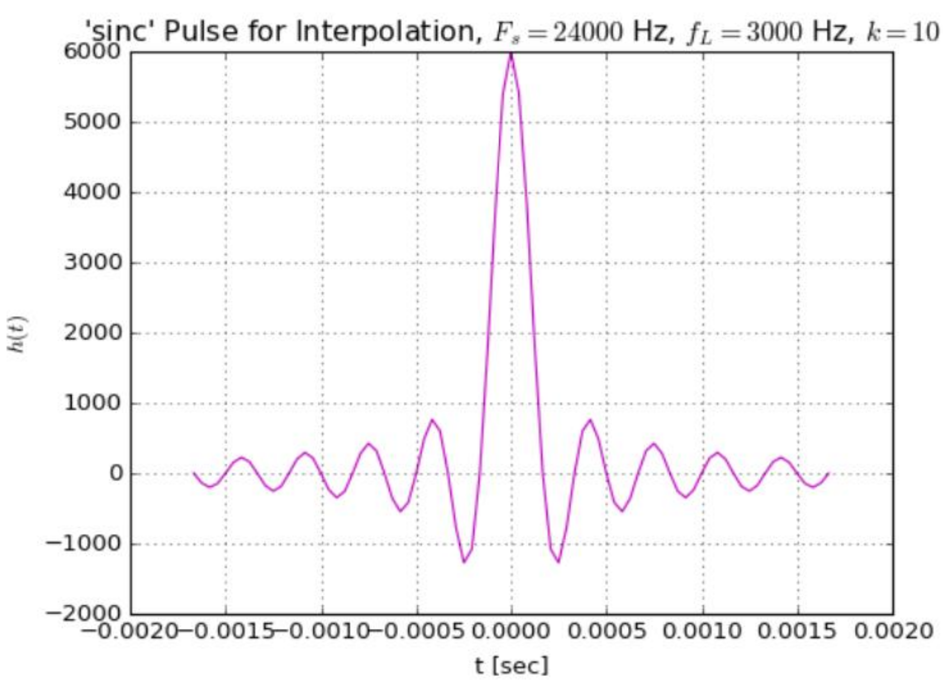
In [7]:
```
FsN = N*Fs  # new sampling rate
ttN = np.arange(xNt.size)/float(FsN)  # new time axis
```

In [8]:
```
# new stem plot
plt.figure(2, figsize=fsz)
plt.stem(ttN[:N*24], xNt[:N*24])
plt.ylim([-1.2, 1.2])
plt.ylabel('$x_N(t)$')
plt.xlabel('t [sec]')
strt2 = 'Expanded by $N={}$ Sine Waveform $x_N(t)$'.format(N)
strt2 = strt2 + ', $f_m={}$ Hz, $F_{{sN}}={}$ Hz'.format(fm, FsN)
plt.title(strt2)
plt.grid()
plt.savefig('sine1000xp3_Fs24000.eps')
```



In [9]:
```
def sinc_ipol(Fs, fL, k):
    """
    sinc interpolation function, cutoff frequency fL,
    taillength k/(2*fL) seconds
    >>>>> tth, ht = sinc_ipol(Fs, fL, k) <<<<<
    where Fs    sampling rate
          fL    cutoff frequency in Hz
          k     taillength in terms of zero crossings of sinc
          tth   time axis for h(t)
          ht    truncated sinc pulse h(t)
    """
    # create time axis
    ixk = int(np.round(Fs*k/float(2*fL)))
    tth = np.arange(-ixk, ixk+1)/float(Fs)
    # sinc pulse
    ht = 2*fL*np.sinc(2*fL*tth)
    return tth, ht
```

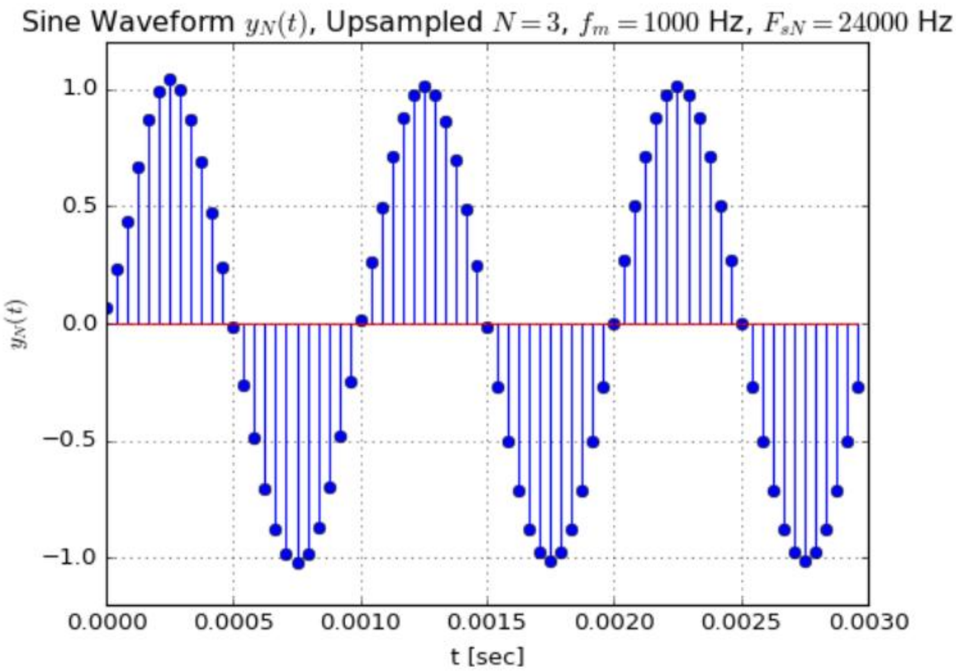
In [10]:
```
# plot of interpolation waveform
fL = 3000   # cutoff frequency
k = 10  # sinc pulse truncation
tth, ht = sinc_ipol(FsN, fL, k)
plt.figure(3, figsize=fsz)
plt.plot(tth, ht, '-m')
plt.ylabel('$h(t)$')
plt.xlabel('t [sec]')
strt3 = "'sinc' Pulse for Interpolation"
strt3 = strt3 + ', $F_s={}$ Hz, $f_L={}$ Hz, $k={}$'.format(FsN, fL, k)
plt.title(strt3)
plt.grid()
plt.savefig('sinc_ipol_fL3000')
```



In [11]:
```
# convolve expanded sine sequence with interpolation waveform to
# obtain upsampled (by factor N) sequence yNt with sampling rate FsN
yNt = np.convolve(xNt, ht, 'same')/float(Fs)
```

In [12]:

```
# stem plot of upsampled sequence
plt.figure(4, figsize=fsz)
plt.stem(ttN[:N*24], yNt[:N*24])
plt.ylim([-1.2, 1.2])
plt.ylabel('$y_N(t)$')
plt.xlabel('t [sec]')
strt4 = 'Sine Waveform $y_N(t)$, Upsampled $N={}$'.format(N)
strt4 = strt4 + ', $f_m={}$ Hz, $F_{{sN}}={}$ Hz'.format(fm, FsN)
plt.title(strt4)
plt.grid()
plt.savefig('sine1000_Fs24000.eps')
```



In [ ]: