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% Tuneup 5.
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```
% Matlab code to generate the spectrograms for Problem 1.4
```

```
fs = 8000;
Ts = 1 / fs;
tmax = 3;
t = 0 : Ts : tmax;
```

```
% Create cosine signal
```

```
f0 = 880;
T0 = 1/f0;
x = cos(2*pi*f0*t);
```

```
% Spectrogram parameters
```

```
blockSize = fs;
overlap = blockSize/2;
```

```
% Plot spectrogram of input signal
```

```
figure;
spectrogram(x, blockSize, overlap, blockSize, fs, 'yaxis');
title('Spectrogram of x(t)');
```

```
% (a) Squaring block
```

```
y = x .^ 2;
figure;
spectrogram(y, blockSize, overlap, blockSize, fs, 'yaxis');
title('Spectrogram of x^2(t)');
```

```
% (b) Cubic block
```

```
y = x .^ 3;
figure;
spectrogram(y, blockSize, overlap, blockSize, fs, 'yaxis');
title('Spectrogram of x^3(t)');
```

```
% (c) Fourth-order
```

```
y = x .^ 4;
figure;
spectrogram(y, blockSize, overlap, blockSize, fs, 'yaxis');
title('Spectrogram of x^4(t)');
```

```
% What frequencies are created in each
% of the three parts?
```

```
% Output for input cos(2 pi f0 t) is
% y(t) = x^k(t) = (cos(2 pi f0 t))^k
```

```

% for a kth-order nonlinearity.
% Substitute for cos(phi)
% (1/2) exp(-j phi) + (1/2) exp(j phi)
% apply the exponentiation and simplify
% the result. The coefficients follow
% Pascal's triangle divided by 2^(k-1).

% (a) For the squaring block,
%  $y(t) = x^2(t) = (\cos(2 \pi f_0 t))^2$ 
% which is  $1/2 + (1/2) \cos(2 \pi (2 f_0) t)$ 
% Output frequencies: { -2 f0, 0, 2 f0 }.

% (b) For the cubic block,
%  $y(t) = x^3(t) = (\cos(2 \pi f_0 t))^3$ 
% which is
%  $1/4 \cos(2 \pi (3 f_0) t) + 3/4 \cos(2 \pi f_0 t)$ 
% Output frequencies: { -3 f0, -f0, f0, 3 f0 }.

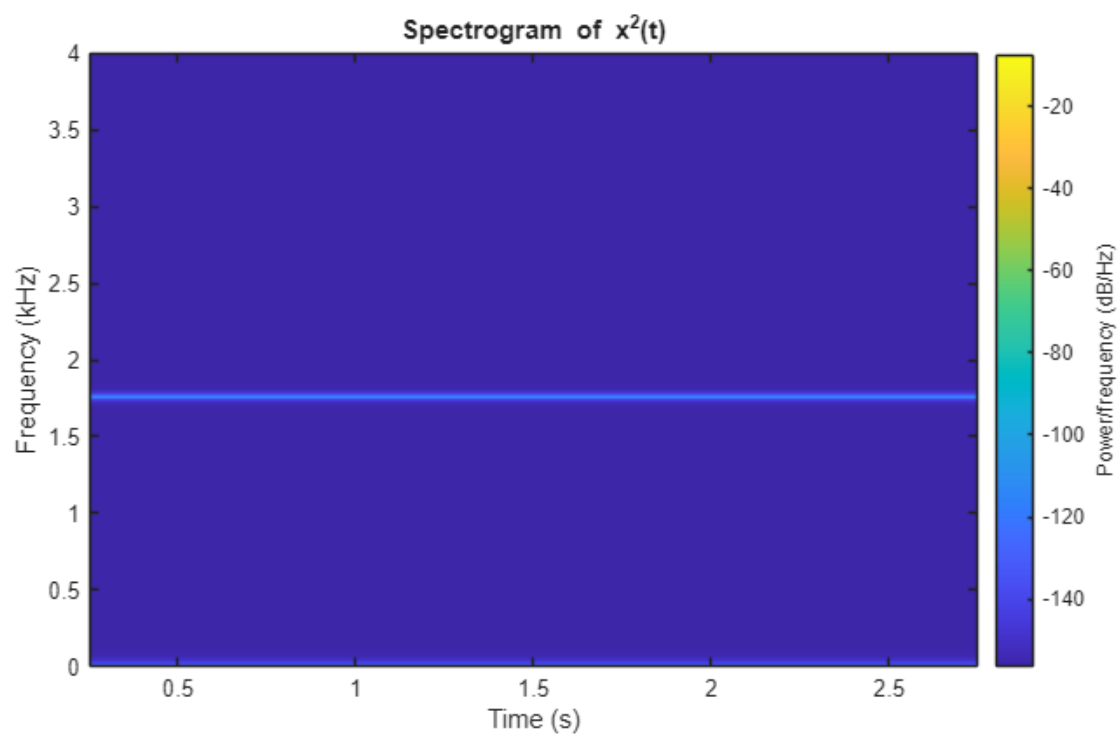
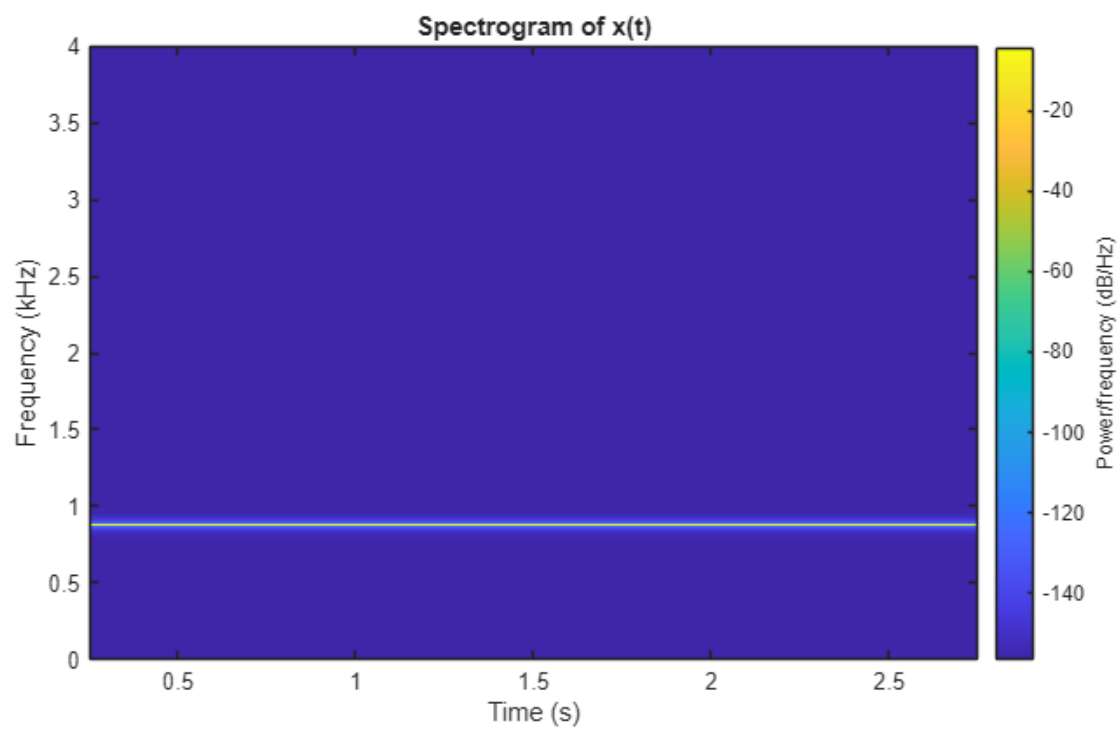
% (c) For a fourth-order block,
%  $y(t) = x^4(t) = (\cos(2 \pi f_0 t))^4$ 
% which is  $y(t) = (x(t)^2)^2 =$ 
%  $(1/2 + (1/2) \cos(2 \pi (2 f_0) t))^2$ 
% or  $y(t) = 3/8 + (1/2) \cos(2 \pi (2 f_0) t) +$ 
%  $1/8 \cos(2 \pi (4 f_0) t)$ 
% Output frequencies: { -4 f0, -2 f0, 0, 2 f0, 4 f0 }.

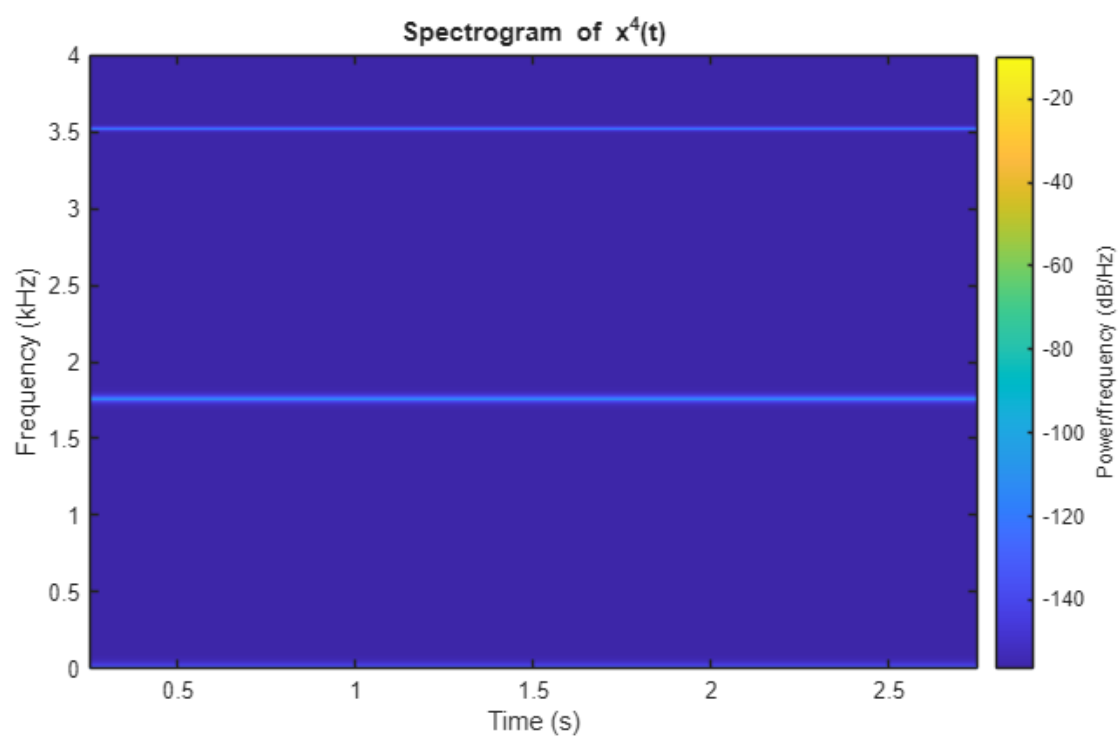
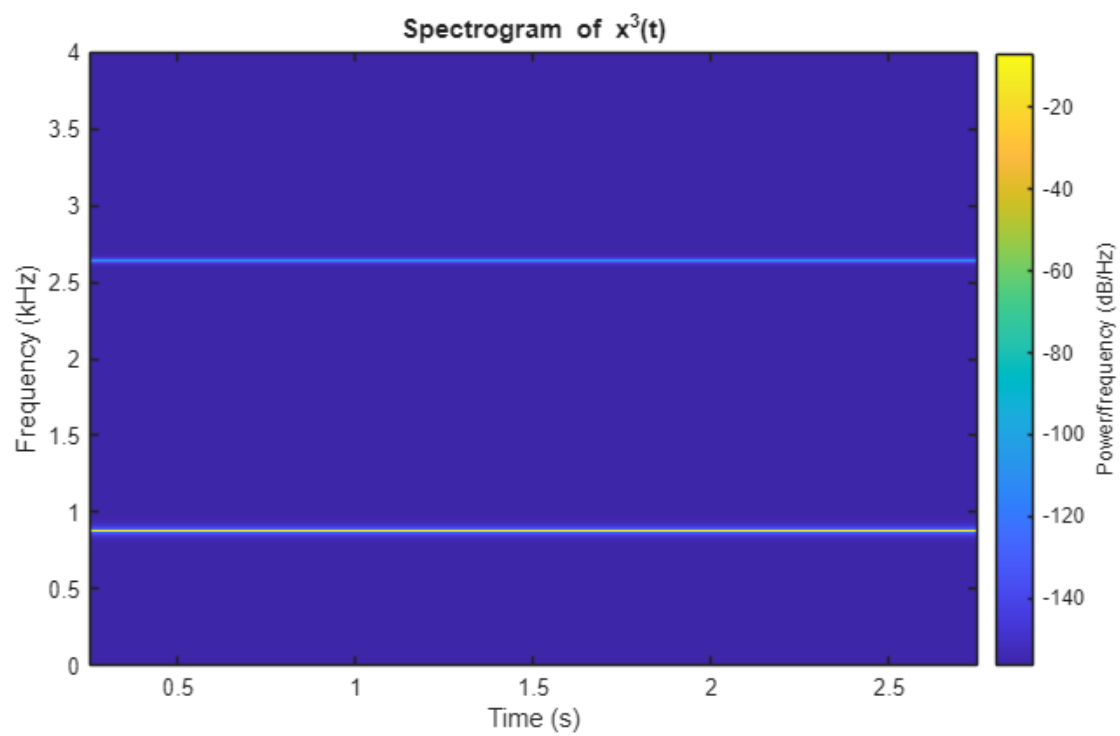
% What happens for the fifth-order case?
% Hint: aliasing.

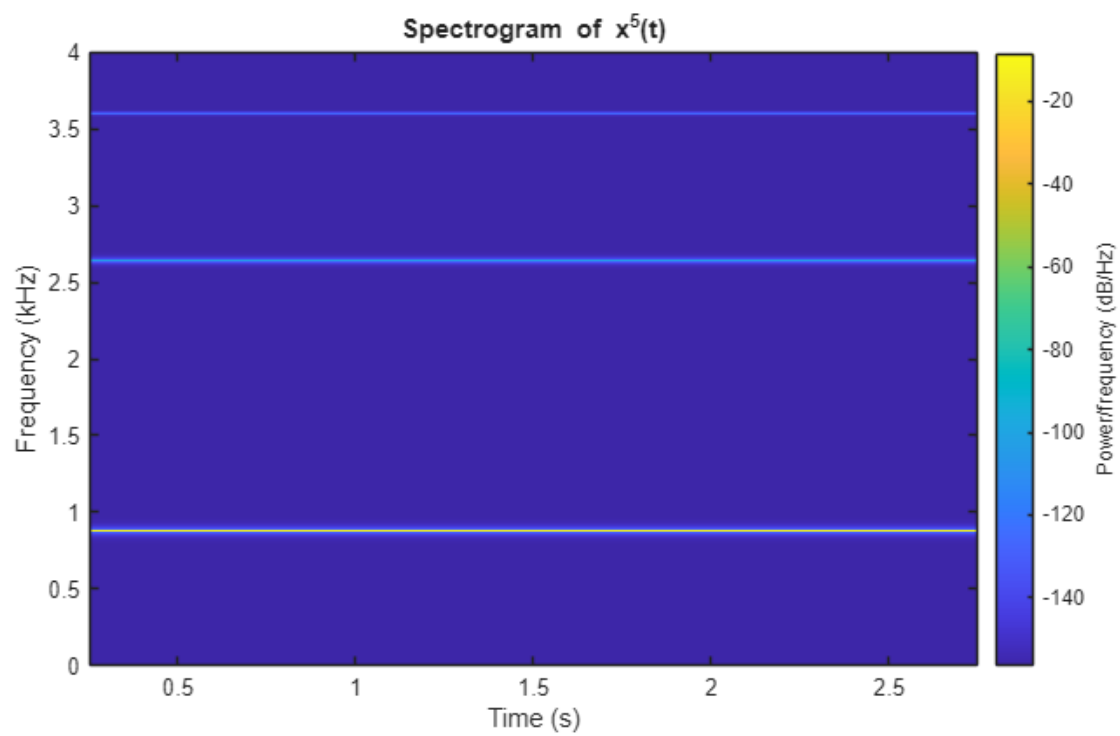
% Matlab code for the fifth-order case
y = x .^ 5;
figure;
spectrogram(y, blockSize, overlap, blockSize, fs, 'yaxis');
title('Spectrogram of  $x^5(t)$ ');

% Inferring from first- through fourth-order
% cases, the fifth-order nonlinearity would
% have frequencies { -5 f0, -3 f0, -f0, f0, 3 f0, 5 f0 }.
% With fs = 8000, any input frequencies at
% or above 4000 Hz would alias. So,
% frequencies -5 f0 and 5 f0 would alias to
% -5 f0 + fs = 3600 Hz and 5 f0 - fs = -3600 Hz.

```







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