There are probably some typographical errors in the following. Please let me know if you find mistakes, so that I can update this document.

2017 “Test 2” (First exam after pretest)

1. (a) $x[n] = 5 \cos(2\pi(0.1)n) + 2 \cos(2\pi(0.8)n)$

   (b) Discrete-time frequencies include $\pm 0.1$ and $\pm 0.2$.

   (c) Possible frequencies have the form $kF_s \pm 2 \text{kHz}$, where $k$ is any integer, and $F_s = 10 \text{kHz}$. The results are 2 kHz, 8 kHz, 12 kHz, 18 kHz, 22 kHz, ….

2. (a) $Y(z) = \frac{2 + 4z^{-1}}{1 + 2z^{-1} + (3/4)z^{-2}} \left( \frac{1}{1 - (0.1)z^{-1}} \right) - \frac{30 + 9z^{-1}}{1 + 2z^{-1} + (3/4)z^{-2}} \quad |z| > 1.5$

   (b) Poles are at $z = -1.5$ and $z = -0.5$. Zeros are at $z = 0$ and $z = -2$. The ROC is $|z| > 1.5$.

   (c) $h[n] = 3 \left( \frac{1}{2} \right)^n u[n] - \left( \frac{3}{2} \right)^n u[n]$

   (d) The system is not stable. Why?

   (e) This is a bogus question. There’s no DC gain associated with an unstable system.

3. (a) $\{ \ldots, 0, 0, 2, \frac{1}{2}, 0, -1.5, \ldots \}$

   (b)

   (c)

4. $x[n] = 3 \left( \frac{1}{2} \right)^n u[n] - 4(3)^n u[-n] + (\sqrt{0.9})^n \cos(2.126n) u[n] + 0.6203(\sqrt{0.9})^n \sin(2.126n) u[n]$

5. There are many valid solutions.

   - Start with the denominator: To obtain clear peaks at $f = \pm 0.25$, place the poles slightly inside the unit circle at angles of $\omega = \pm 2\pi(0.25) = \pm \pi/2$. So the denominator must have the form

     $$(z - re^{j\pi/2})(z - re^{-j\pi/2}) = (z - jr)(z + jr) = z^2 + r^2$$

     ($r < 1$ is required for stability.) So valid denominators must have the form $a_0 = 1, a_1 = 0, a_2 = r^2$, where $r$ is slightly less than 1. (I used $r = 0.9$ in the solution below.)

   - To reject $f = 3/8$, place the filter zeros on the unit circle at angles of $\omega = \pm 2\pi(3/8) = \pm 3\pi/4$. These zeros, along with the filter gain factor $G$ form the numerator polynomial:

     $$G(z - e^{j3\pi/4})(z - e^{-j3\pi/4}) = Gz^2 + \sqrt{2}Gz + G$$

     This gives $b_0 = b_2 = G$, and $b_1 = \sqrt{2}G$. The value of $G$ must be selected to give a DC gain (measured at $z = 1$ of 1.0, giving $\sum b_k = suma_k$.

     An example solution using $r = 0.9$ is

     $$H(z) = \frac{0.53z^2 + 0.53\sqrt{2}z + 0.53}{z^2 + 0.81} \quad b_0 = b_2 = 0.53, b_1 = 0.53\sqrt{2}, a_0 = 1, a_1 = 0, a_2 = 0.81$$

6. This is a non-causal, stable FIR filter with $H(f) = 2 + 2\cos(2\pi f)$. The filter gain at $f = 0.1$ is 3.619 (with no phase shift), so the system output for part “g” is $y[n] = 10.854\sin(2\pi(0.1)n)$. 

ECE-486 Selected Test Problem Answers
2016 “Test 2” (First exam after pretest)

1. (a) \( h(n) = \{ \ldots, 0, b, 0, -\frac{5}{4}b, 0, \frac{5}{16}b, \ldots \} \)

(b) \( H(z) = \frac{b z^2 - 1}{z^2 + 0.25} \quad |z| > 0.5 \)

(c) \( H(f) = \frac{b e^{j4\pi f} - 1}{e^{j4\pi f} + 0.25} \), \( b = 3/8 \).

(d) There are lots of valid forms for the solution. Check your result using part 1a.

(e) A valid sketch should show zero gain at \( f = -1, -0.5, 0, 0.5, 1.0 \). The gain should show peaks with magnitude \((8/3)b = 1.0\) at \( f = .75, -0.25, 0.25, 0.75\).

2. (a) \( h(n) = \left( \frac{1}{2} \right)^n u(n) + \left( \frac{1}{2} \right)^{n-1} u(n-1) \)

(b) \( y(n) = \frac{1}{2} y(n-1) = x(n) + x(n-1) \)

(c) (Shown on right)

(d) \( y(n) = -5 \left( \frac{1}{4} \right)^n u(n) + 6 \left( \frac{1}{2} \right)^n u(n) \)

3. (a) \( H(z) = \frac{kz + 1}{z + k} \quad |z| > |k| \)

(b) Require \(|k| < 1\)

(c) \( |H(f)|^2 = \frac{k^2 + 2k \cos(2\pi f) + 1}{1 + 2k \cos(2\pi f) + k^2} = 1 \)

(d) Transposed System Equations:

\[ y(n) = k x(n) + v(n - 1) \]
\[ v(n) = x(n) - ky(n) \]

4. (a) The filter must remove signals that are from 30 to 50 Hz above or below every multiple of 150 Hz: Bands that will alias onto the desired signal include: \( 30 < F < 50, 100 < F < 120, 250 < F < 270 \), etc.

Lower Stopband: \(|F| < 120 \) Hz. Upper Stopband: \(|F| > 250 \) Hz.

(b) \( f_0 = -4/15 = -0.2666, b_0 = 1/15 = 0.0666 \).
2015 “Test 2” (First exam after pretest)

1. (a) 
\[ H(z) = 12.5 \frac{z^2 - z + 1}{z^2 + 0.25} \quad |z| > 0.5 \]

(b) The correct answer has many valid (equivalent) expressions. One choice:
\[ h(n) = 12.5(0.5)^n \cos((\pi/2)n)u(n) - 25(0.5)^n \sin((\pi/2)n)u(n) + 25(0.5)^{n-1} \sin((\pi/2)(n-1))u(n-1) \]

(c) This is a stable system (The ROC includes |z| = 1).

(d) \[ y(n) + 0.25y(n-2) = 12.5x(n) - 12.5x(n-1) + 12.5x(n-2) \]

(e) Plot “F”

2. (a) \[ x(n) = -10\delta(n) + 24(3/4)^nu(n) + 24(4/3)^nu(-n-1) \]

(b) \[ X(z) = \frac{-z}{z - 2} + 3 + \frac{5}{z - 1} + \frac{7}{8} \left( \frac{1}{z - 7/8} \right) \quad 1 < |z| < 2 \]

3. (a) Poles are at \( 0.7 \pm j0.6409 \). Zeros are at \( z = \pm 1 \).
\[ H(z) = \frac{z^2 - 1}{z^2 - 1.4z + 0.9} \quad |z| > \sqrt{0.9} \approx 0.95 \]

(b) The system is stable.

(c)

(d) Plot “C”

4. (a) \[ x(n) = 3 \cos(2\pi(0.7)n) \]

(b)

(c) Plot “E”
2014 “Test 2” (First exam after pretest)

1. \( x(n) = 21\delta(n+5)+\delta(n+3)+6(2)^n u(n)+5(-3)^n u(-n-1)+2(0.5)^n \cos\left(\frac{\pi}{3} n\right) u(n)-\frac{10}{\sqrt{3}} (0.5)^n \sin\left(\frac{\pi}{3} n\right) u(n) \)

2. There are many valid solutions. Transfer functions must have zeros at \( \exp(\pm j 2\pi(0.06)) \), so the numerator polynomial must be proportional to \( z^2 - 1.8596z + 1 \). All poles must be inside the unit circle, and the DC gain (obtained at \( z = 1 \)) must be 1. The following is one example solution:

   (a) \( H(z) = \frac{G(z - e^{j2\pi(0.06)}) (z - e^{-j2\pi(0.06)})}{(z - 0.5)(z - 1)} = G\frac{z^2 - 1.8596z + 1}{z^2 - 0.6z + 0.05} \)

   Set \( G = 3.2041 \) to satisfy the DC gain requirement:

   \[ H(z) = \frac{3.2041z^2 - 5.9583z + 1}{z^2 - 0.6z + 0.05} \]

   (b) \( y(n) - 0.6y(n-1) + 0.05y(n-2) = 3.2041x(n) - 5.9583x(n-1) + 3.2041x(n-2) \)

   (c) \( 3. (a) x(n) = 10 \cos(2\pi(0.35)n) + 0.5 \cos(2\pi(0.05)n) \).

   (b) \( f = \pm 0.35 \) and \( f = \pm 0.05 \).

   (c) Periodic. Period = 20 samples.

   (d) No z-transform exists.

   (e) \( x(n) = 5e^{j2\pi(0.35)n} + 5e^{-j2\pi(0.35)n} + 0.255e^{j2\pi(0.05)n} + 0.25e^{-j2\pi(0.05)n} \)

   \[ X(f) = \sum_{k=-\infty}^{\infty} 5\delta(f - 0.35 - k) + 5\delta(f + 0.35 - k) + 0.25\delta(f - 0.05 - k) + 0.25\delta(f + 0.05 - k) \]

3. (a) \( h(n) = 10.01 \sin(0.1n) u(n) \)

   (c) \( y(10) = 37.2 \).

   (d) \( Y(z) = \frac{z^2}{(z^2 - 1.99z + 1)(z - 1)} + \frac{-5z + 6.95z^2}{z^2 - 1.99z + 1} \)

   (e) DC component = 100.
2013 Test 1

1. (a) 
\((1.1)^{n+2}u(n + 2)\)
(b) 
\(\delta(n + 3) - 3\delta(n - 5)\)
(c) Check: 
x(0) = 0.375, x(-2) = x(2) = 0.041666.
(d) Check: Your **REAL** answer should give 
x(3) = 6, x(4) = -20.

2. (a) Your solution should begin with:

\[h(n) = \{\ldots, 0, 2, 1, -0.5, +0.5, \ldots\}\]

(b) 
\[y(n) + \frac{1}{4}y(n - 1) - \frac{3}{8}y(n - 2) = 2x(n) + \frac{3}{2}x(n - 1) - x(n - 2)\]

(c) Stable

(d)

(e)

(f) 2.857

3. \(H(z) = 0.0913 \left(\frac{z + 1}{z - 0.8174}\right)\)

4. (a) Upper Stopband: \(|F| > 132\) MHz.
Lower Stopband: \(|F| < 32\) MHz

(b)
2011 Test 1

1. Valid solutions must have zeros at \( z = e^{\pm j2\pi(60/400)} \) and must satisfy \( H(z)|_{z=1} = \sum h(n) = 5 \). The minimum order solution has just the two required zeros:

\[
H(z) = Gz^{-2}(z - e^{j2\pi(60/400)})(z - e^{-j2\pi(60/400)}) \\
= Gz^{-2}(z^2 - 2\cos(2\pi(60/400))z + 1) \\
= Gz^{-2}(z^2 - 1.175z + 1)
\]

Setting \( H(1) = 5 \) gives \( G = 6.065 \).

\[
h(n) = \{ \ldots, 0, 0, 6.065, -7.13, 6.065, 0, 0, \ldots \} \\
H(f) = H(z)|_{z=e^{j2\pi f}} = 6.065e^{-j2\pi f}(2\cos(2\pi f) - 1.175) \\
|H(f)| = 6.065|2\cos(2\pi f) - 1.175|
\]

2. (a) \( h(n) = \delta(n) - \alpha\delta(n - R) \)

\( H(z) = 1 - \alpha z^{-R} \).

(b) The system is stable for any finite \( \alpha, R \). If \( x(n) \) is bounded, \(|x(n)| < B\), then \( y(n) < (1 + |\alpha|)B\).

(c) \( |H(\omega)| = \sqrt{1 + \alpha^2 - 2\alpha \cos(\omega R)} \).

\( |H(\omega)| \) has a maximum value of \( 1 + \alpha \) when \( \omega R \) is an odd multiple of \( \pi \)

\( |H(\omega)| \) has a minimum value of \( 1 - \alpha \) when \( \omega R \) is an even multiple of \( \pi \)

Your plot should show a periodic \( |H(\omega)| \) with five full cycles from \(-\pi\) to \( \pi\).

3. (a)

\[
H(z) = \frac{2}{3} \left( \frac{z-2}{z-3/4} \right), \quad |z| > 3/4
\]

(b)

\[
2/3 \left( \frac{3}{4} \right)^n u(n) - 4/3 \left( \frac{3}{4} \right)^{n-1} u(n-1)
\]

(c)

\[
y(n) - \frac{3}{4} y(n-1) = \frac{2}{3} x(n) - \frac{4}{3} x(n-1)
\]

(d) The system is causal \( (h(n) = 0 \text{ for } n < 0) \). The system is stable since all poles are inside the unit circle.

4. (a) Require \( F_s > 2B = 20 \text{ kps} \).

(b) \( F_s > 10 \text{ kps} \) is sufficient.

5. (a) Your plot should show (Dirac) delta functions at DC, \pm 0.0417, \pm 0.0833, \pm 0.4792, \pm 0.4375, \pm 0.3958 cycles/sample. The corresponding impulse magnitudes are \( |A_0|, |A_2/2|, |A_4/2|, |A_1/2|, |A_3/2|, \text{ and } |A_5/2| \) respectively.

(b) Select \( f_0 = -23/48 = -0.48 \). The filter stopband must include \(|f| > \frac{2}{48} = 0.0416\). The filter output will be \( A_1/2 \).
2010 Test 1

1. 

\[ x(n) = 7\delta(n) + 2\delta(n+1) + 3\delta(n-1) + 5\delta(n+3) + 4 \left( \frac{2}{0.6\sqrt{3}} \right) (0.6)^{n+1} \sin \left( \frac{\pi}{3} (n+1) \right) u(n+1) - 5(1.1)^{n-1} u(-n). \]

2. (a) 

\[ H(z) = \frac{(1/3)z^2 + (7/24)z}{z^2 - (1/4)z - (1/8)} \]

(b) \(|z| > 0.5. \)

(c) Yes. The ROC includes \(|z| = 1. \)

(d) 

(e) 

\[ h(n) = \frac{-5}{18} \left( -\frac{1}{4} \right)^n u(n) + \frac{11}{18} \left( \frac{1}{2} \right)^n u(n) \]

(f) 

\[ y(n) - \frac{1}{4} y(n-1) - \frac{1}{8} y(n-2) = \frac{1}{3} x(n) + \frac{7}{24} x(n-1). \]

3. (a) \( y(5) = 5h(3) + 10h(1) = 33.51. \)

(b) 

\[ y(n) = A \left( \frac{1}{2} \right)^n u(n) + B \left( \frac{3}{4} \right)^n u(n) + C u(n) \]

(c) 

\[ \lim_{n \to \infty} y(n) = C = \frac{32}{3} \]

(d) 960 (constant)

4. (a) 

\( H_{C0}(F) \) Passband: \(|F| < 20 \text{ kHz}\) \quad \( H_{C0}(F) \) Stopband: \(|F| > 24 \text{ kHz}\)

(b) 

\( H_{C1}(F) \) Passband: \(|F| < 20 \text{ kHz}\) \quad \( H_{C1}(F) \) Stopband: \(|F| > 156 \text{ kHz}\)

\( H(f) \) Passband: \(|f| < 0.113636 \) \quad \( H(f) \) Stopband: \(|f| > 0.136364 \)
2009 Test 1

1. 
\[ x(n) = \left( \frac{-1}{2} \right)^n u(n) - 4 (2)^{n-1} u(-n) - 2 \left( \frac{1}{2} \right)^{n-1} u(n-1) + 3 \cos((\pi/4)n)u(n) + 4 \sin((\pi/4)n)u(n) \]

2.  
(a) This part implies that \( k = 1 \) and \( a = c \).
(b) This part implies that \( b = a + c = 2a \).
(c) Use the above (and convolution) to show \( y(2) = (9/4)a \). So \( a = 2 \) is known.

\[ k = 1, \ a = 2, \ b = 4, \ c = 2 \]
\[ h(n) = \{ \ldots, 0, 0, 2, 4, 2, 0, 0, \ldots \} \]
\[ h_R(n) = \{ \ldots, 0, 0, 2, 4, 2, 0, 0, \ldots \} \]
\[ H_R(f) = 4 + 4 \cos(2\pi f) \]

3.  
(a) 
\[ Y^+(z) = \frac{-10 + z^{-1}}{1 - (2/3)z^{-1} + (1/12)z^{-2}} \]

(b) 
\[ \beta = 3/4 = 0.75, \ \alpha = -13/2 = -6.5 \]

4. Part c: Any band of frequencies offset multiples of 300 MHz from the \( 50 < \|F\| < 100 \) MHz bands could cause trouble. The following bands must be removed:

\[
\begin{align*}
200 < |F| &< 250 \text{ MHz} & 350 < |F| &< 400 \text{ MHz} \\
500 < |F| &< 550 \text{ MHz} & 650 < |F| &< 700 \text{ MHz} \\
800 < |F| &< 850 \text{ MHz} & 950 < |F| &< 1000 \text{ MHz}
\end{align*}
\]
5. A causal linear time-invariant system has poles at \( z = \frac{3}{4} \) and \( z = -\frac{1}{2} \), and zeros at \( z = 1.5e^{j\pi/3} \) and \( z = 1.5e^{-j\pi/3} \). The system has a DC gain of 10.

(a) \[
H(z) = \frac{30}{14} \left( \frac{z^2 - (3/2)z + 9/4}{z^2 - (1/4)z - 3/8} \right) \quad |z| > 3/4
\]

(b) \[
h(n) = A(3/4)^nu(n) + B(-1/2)^nu(n)
\]

(c) Stable

(d) Use a direct-form II implementation of the following:

\[
y(n) - (1/4)y(n-1) - (3/8)y(n-2) = (30/14)[x(n) - (3/2)x(n-1) + 9/4x(n-2)]
\]
2008 Test 1

1. (a) Y, Y, N, Y
   (b) X, N, X, X
   (c) N, Y, Y, N

2. 
   \[ x(n) = \delta(n+2) + 5 \left( \frac{1}{2} \right)^{n-2} u(n-2) - (-3)^{n+1} u(-n-2) - (-3)^{n-1} u(-n) \]

3. (a) Yes
   (b) \( y(3) = 31 \)
   (c) \( H(0) = 10, H(0.25) = 2, H(0.5) = 2. \)

4. (a) \( h(n) = \alpha^n u(n) + \beta \alpha^{n-1} u(n-1) \)
   (b) \[ H(z) = \frac{z + \beta}{z - \alpha} \quad |z| > \alpha \]
   (c) Causal
   (d) Stable only if \( |\alpha| < 1. \)

5. (a) \( h(n) = 2u(n) \)
   (b) Unstable
   (c) \( y(n) = 2u(n-3) - 0.5(0.5)^n u(n) + 3u(n) \).
   (d) Make it beautiful!

6. (a) Must reject \( 400k - 120 < |F_{kHZ}| < 400k - 80 \) and \( 400k + 80 < |F_{kHZ}| < 400k + 120 \) for any integer \( k \).
   (b) \( 0.2 < f < 0.3 \)
   (c) \( f_0 = 0.25, \quad e^{-j2\pi(0.25)n} = \{ \ldots, j, -j, 1, -j, 1, j, -1, 1, j, -1, \ldots \} \)
   (d) \( F_s = 80 \text{ kmps} \)
2006 Test 1

1. \[ x(n) = 5\delta(n) + (0.5)^{n-1}u(n-1) + (0.25)^nu(n) - 2(-1)^nu(-n-1) - 4(-2)^nu(-n-1) \]

2. (a) \[ z^2 + 2z + 3 + 4z^{-1}, \text{ for } z \neq 0 \text{ and } z \neq \infty. \]
   (b) \[ X(z) = \frac{5}{2}e^{j\pi/6} \left( \frac{z}{z-e^{j2\pi(0.3)}} \right) + \frac{5}{2}e^{-j\pi/6} \left( \frac{z}{z-e^{-j2\pi(0.3)}} \right) \quad |z| > 1, \]
   -OR-
   \[ X(z) = \frac{5\sqrt{3}}{2} \left( \frac{1 - z^{-1}\cos(2\pi(0.3))}{1 - 2z^{-1}\cos(2\pi(0.3)) + z^{-2}} \right) - \frac{5}{2} \left( \frac{z^{-1}\sin(2\pi(0.3))}{1 - 2z^{-1}\cos(2\pi(0.3)) + z^{-2}} \right) \quad |z| > 1 \]
   (c) \[ X(z) = \frac{1}{2} + z^{-1} + 2\frac{z^{-1}}{z - 0.5} \quad |z| > 0.5 \]

3. (a) \[ g(n) = g(n-1) + g(n-2) \]
   (b) \[ g(-1) = 0, g(-2) = 1. \]
   (c) \[ g(n) = A \left( \frac{1 - \sqrt{5}}{2} \right)^n u(n) + B \left( \frac{1 + \sqrt{5}}{2} \right)^n u(n) \]
   \[ A = \frac{1}{2} - \frac{1}{2\sqrt{5}}, \quad B = \frac{1}{2} + \frac{1}{2\sqrt{5}} \]
   (d) Unstable.

4. (a) A,B,C
   (b) C only
   (c) A

5. (a) Passband: \( 50 \text{ kHz} < |F| < 60 \text{ kHz} \).
   Stopbands: \(|F| < 30 \text{ kHz}\) and \(|F| > 100 \text{ kHz}\).
   (b) You should have signal components (in the correct orientation) for \( 1/4 < |f| < 3/8 \) and for \( 5/8 < |f| < 3/4 \). The peak spectrum value is \((80 \times 10^3)A\).
   (c) Use \( f_o = 5/16 \) (or \( f_o = -11/16 \)).
   (d) The signal should be centered in the band \(-1/16 < f < 1/16\), with increasing slope, and peak spectrum value \((80 \times 10^3)A\).
   (e) \( B = 1/16 \).
1. (a) \( X(z) = z + 1 + z^{-1} \), for \( z \neq 0, z \neq \infty \).

(b) \( Y(z) = 1 - \frac{z}{z + 1} = \frac{1}{z + 1} \), for \( |z| < 1 \). (Problem not graded because of confusion about the question.)

(c) \( \frac{-1}{z - 1} \), for \( |z| < 1 \).

(d) \( \frac{z}{z - 1/2} - \frac{z}{z - 2} \), for \( 1/2 < |z| < 2 \).

2. \( x(n) = u(n) + \delta(n + 1) + 6(2)^n u(n) + +5(3)^{n-1} u(-n) - 0.5(4)^{n+2} u(-n - 3) - 0.5(-4)^{n+2} u(-n - 3) \)

3. (a) \( H(z) = \frac{(2.4) z}{z - 5} \), for \( |z| > 5 \).

(b) Zero at \( z = 0 \), pole at \( z = 5 \), ROC outside of \( |z| = 5 \) circle.

(c) Not stable.

(d) \( h(n) = (2.4)(5)^n u(n) \)

(e) \( y(n) = 3(5)^n u(n) - (0.6)u(n) + 15(5)^n u(n) \).

4. List frequencies which alias with \( \pm 950 \) Hz. For \( F_s = 10 \) ksp, these are \( 10 \) kHz \( \pm 950 \) Hz, \( 20 \) kHz \( \pm 950 \) Hz, \( 30 \) kHz \( \pm 950 \) Hz, \( 40 \) kHz \( \pm 950 \) Hz, \ldots .

5. (a) \( \frac{z}{z - W_N^{-k}} \), for \( |z| > 1 \).

(b) \( h(n) = W_N^{-nk} u(n) \)

(c) Not stable.

(d) Causal.

(e) IIR

(f) Evaluate the convolution sum at \( n = N \) to get

\[ y(N) = \sum_{\ell=0}^{N-1} x(\ell) W_N^{\ell k} \]

6. (a) \( 0.8 < |z| < 2 \)

(b) No. If the ROC includes \( |z| = 1 \), then the pole at \( z = 2 \) implies a left-handed (non-causal) portion of \( h(n) \).

(c) Three systems. (Three possible ROC assignments)

(d) \( H(z) = A \frac{(z - 1.5e^{j\pi/6})(z - 1.5e^{-j\pi/6})(z + 1)}{(z + .8)(z - 2)} \)

\[ = A \frac{(z^2 - 3 \cos(\pi/6) z + 2.25)(z + 1)}{(z + .8)(z - 2)} \]

Determine \( A \) so that \( H(1) = 1 \): \( A = (-1.8)/(2(3.25 - 3 \cos(\pi/6))) \).
The diagram shows the frequency response $X_c(F)$ with a peak at $0.5$ at $F = 9 \times 10^3$ and another at the same magnitude at $F = -9 \times 10^3$. The spectrum $X(f)$ is periodic with peaks at $f = -1 - 3/16$, $-1 + 3/16$, $3/16$, $3/16$, $1 - 3/16$, and $1 + 3/16$. The discrete-time spectrum $X(k)$ has a peak at $k = 3$ and another at $k = 13$. The magnitude at each point is indicated by a vertical arrow.