

DSP Midterm Exam

Monday, May 24, 2021

Question 1: T or F, Multiple Choice, and Short Answer (Estimated time: 5-10 minutes)

1. **T** or **F**: The time index n for DT signals usually has units of seconds.
2. **T** or **F**: DT signals are typically plotted as a series of lollipops.
3. **T** or **F**: A DT frequency of π is considered a high frequency.
4. **T** or **F**: A DT frequency of 2π is considered a low frequency.
5. **T** or **F**: The DTFT of a DT signal is periodic with a period of 2π .
6. The DTFT of a rectangle is a:
 - (a) Sine wave
 - (b) Periodic sinc**
 - (c) Rectangle
 - (d) None of the above
7. The DTFT of a single impulse is:
 - (a) A single impulse
 - (b) A constant**
 - (c) Infinite
 - (d) None of the above

8. A DT signal is given as follows:

$$x(n) = (3\delta(n) - 5\delta(n-1) + 3\delta(n-2))u(n+1)$$

The value of $x(n)$ at $n = 3$ is:

(a) 0

(b) 0.25

(c) 0.5

(d) 1

(e) None of the above

$$\begin{aligned} x(3) &= (3\delta(3) - 5\delta(2) + 3\delta(1))u(4) \\ &= (0 - 0 + 0)1 = 0 \end{aligned}$$

9. A DT signal $x(n]$ is given as follows:

$$x(n) = 101$$

The length of $x(n]$ is:

- (a) 0
- (b) 1
- (c) 101
- (d) ∞**
- (e) None of the above

10. A DT signal $x(n]$ is given as follows:

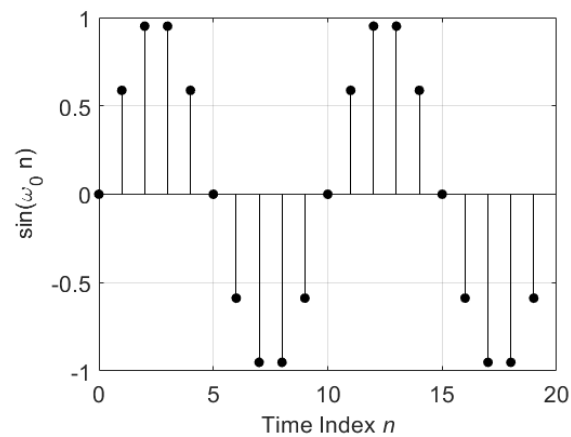
$$x(n) = \text{rect}_5(n)$$

We want to create a new signal $y(n]$ that is identical to $x(n]$ but is centered about $n = 0$ (i.e., we want a rectangle that is symmetric about time zero). To create $y(n]$, we should use:

- (a) $y(n) = x(2n)$
- (b) $y(n) = x(n + 2)$**
- (c) $y(n) = x(n - 2)$
- (d) $y(n) = x(n + 2) + x(n - 2)$
- (e) None of the above

The normal length-5 rectangle starts at $n = 0$ and goes to $n = 4$:
 $\text{rect}_5(n) = \delta(n) + \delta(n - 1) + \delta(n - 2) + \delta(n - 3) + \delta(n - 4)$
We want the rectangle to start at time $n = -2$ and go to time $n = 2$, so we need to shift to the left by two samples via $n \rightarrow n + 2$:
 $\text{rect}_5(n + 2) = \delta(n + 2) + \delta(n + 1) + \delta(n) + \delta(n - 1) + \delta(n - 2)$

11. Two cycles of a DT sine wave $\sin(\omega_0 n]$ are shown in the following plot:



The value of ω_0 is:

- (a) $1/5$
- (b) $\pi/5$**
- (c) 5
- (d) 5π
- (e) None of the above

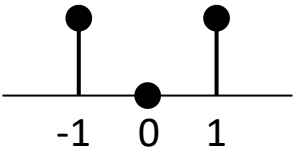
Looking at the signal, 1 cycle contains 10 samples.
But, 1 cycle = 2π radians, thus in 2π radians there are 10 samples:
$$\omega_0 = \frac{2\pi}{10} = \frac{\pi}{5}$$

12. Two DT signals, $x_1(n)$ and $x_2(n)$, are given as follows:

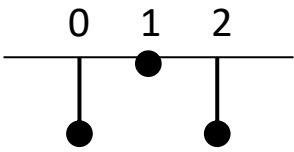
$$x_1(n) = \delta(n + 1) + \delta(n - 1)$$
$$x_2(n) = \delta(n) - \delta(n - 1)$$

In the space provided below, sketch the convolution of these two signals. You must show your work to receive credit.

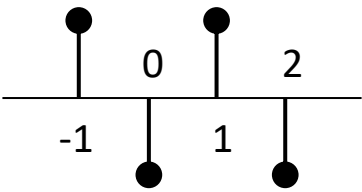
(Note: All lollipops have height 1 or -1)



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$1x_1(n - 0)$
This is $x_1(n)$ scaled by 1 and shifted by 0 (i.e., simply $x_1(n)$) due to the first term in $x_2(n)$.

$-1x_1(n - 1)$
This is $x_1(n)$ scaled by -1 and shifted by -1 due to the second term in $x_2(n)$.

13. A DT signal $x(n)$ is given as follows:

$$x(n) = \delta(n + 2) + 2\delta(n) + \delta(n - 2)$$

Which of the following is the DTFT $X(e^{j\omega})$ of this signal?

(a) $e^{j2\omega} + 2 + e^{-j2\omega}$

(b) $2e^{j\omega} + 2 + 2e^{-j\omega}$

(c) $\delta(2\omega) + 2\delta(\omega) + \delta(-2\omega)$

(d) $2\delta(\omega) + \delta(2\omega) - 2\delta(\omega)$

(e) None of the above

Use the table of transform pairs:
 $\delta(n) \leftrightarrow 1$
 $\delta(n - n_0) \leftrightarrow e^{-j\omega n_0}$

14. In simple terms, describe the key difference between the DTFT of $\text{rect}_3(n)$ and the DTFT of $\text{rect}_3(n + 1)$:

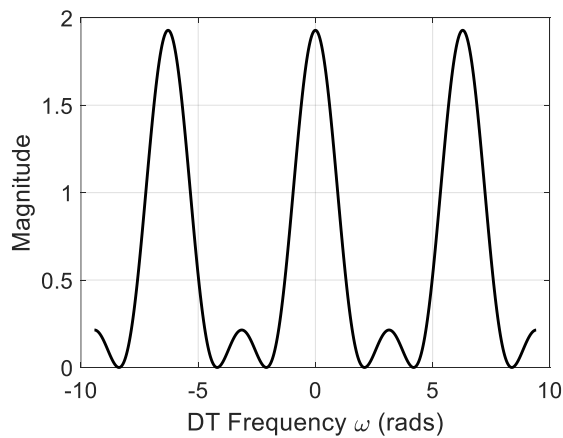
Both have the same magnitude spectrum, but their phase spectra differ.
Specifically, the phase spectrum of the first rectangle is $-\omega$ (with jumps of $\pm\pi$ when the magnitude spectrum is negative).
The phase spectrum of the second rectangle is zero (with jumps of $\pm\pi$ when the magnitude spectrum is negative).

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15. A DT signal $x(n]$ has a magnitude spectrum as shown below (showing the range -3π to $+3\pi$):

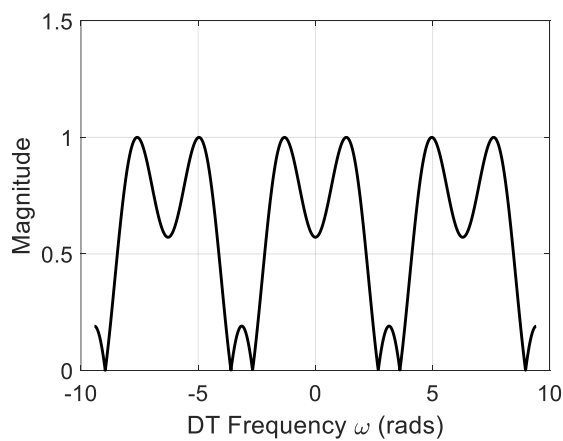


A shift in the time domain causes a phase change in the frequency domain, thus the magnitude spectrum is the same.

The magnitude spectrum of $x[n - 2]$ would look like:

<p>(a)</p> <p>This option shows a magnitude spectrum that is identical to the original spectrum of $x[n]$. It has peaks at $\omega = -6, 0, 6$ with a magnitude of 2, and smaller peaks at $\omega = -3, 3$ with a magnitude of approximately 0.25. The background of the plot area is highlighted in yellow.</p>	<p>(b)</p> <p>This option shows a magnitude spectrum with peaks at $\omega = -6, 0, 6$ with a magnitude of 2. However, there are also significant peaks at $\omega = -3, 3$ with a magnitude of approximately 1.8, which is different from the original spectrum.</p>
<p>(c)</p> <p>This option shows a magnitude spectrum with peaks at $\omega = -6, 0, 6$ with a magnitude of 2. There are also small peaks at $\omega = -3, 3$ with a magnitude of approximately 0.25, matching the original spectrum.</p>	<p>(d)</p> <p>This option shows a magnitude spectrum with peaks at $\omega = -6, 0, 6$ with a magnitude of 2. There are no smaller peaks at $\omega = -3, 3$, which is different from the original spectrum.</p>
<p>(e) None of the above</p>	

16. A DT signal $x(n]$ has a magnitude spectrum as shown below (showing the range -3π to $+3\pi$):

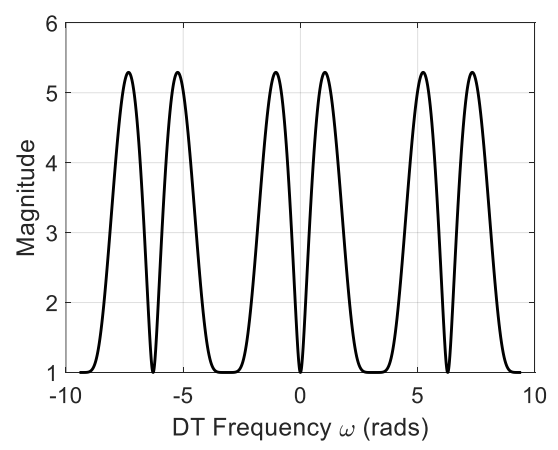


Multiplying by a scalar in the time domain does the same multiplication in the frequency domain ($-1.5 \times$) but the negative will not show in the magnitude spectrum.

The magnitude spectrum of $-1.5x[n]$ would look like:

<p>(a)</p> <p>This plot is identical to the original magnitude spectrum of $x[n]$, with peaks at 1.0 and nulls at $\pm\pi/3$ and $\pm2\pi/3$.</p>	<p>(b)</p> <p>This plot shows the magnitude spectrum of $-1.5x[n]$. The peaks at $\omega = 0, \pm\pi, \pm2\pi, \pm3\pi$ have a magnitude of 1.5. The smaller peaks at $\omega = \pm\pi/2, \pm3\pi/2$ have a magnitude of approximately 0.9. The nulls at $\omega = \pm\pi/3, \pm2\pi/3, \pm4\pi/3, \pm5\pi/3$ remain at zero.</p>
<p>(c)</p> <p>This plot is identical to the original magnitude spectrum of $x[n]$.</p>	<p>(d)</p> <p>This plot shows the magnitude spectrum of $-1.5x[n]$, identical to option (b). The entire plot area is highlighted with a yellow background.</p>
<p>(e) None of the above</p>	

17. A DT signal $x(n]$ has a magnitude spectrum as shown below (showing the range -3π to $+3\pi$):



Multiplying by $\cos(\pi n)$ in the time domain will horizontally shift the spectrum by π .

The magnitude spectrum of $\cos(\pi n) x[n]$ would look like:

<p>(a)</p> <p>This plot is identical to the original magnitude spectrum of $x[n]$, with six peaks at $\omega = -9, -5, -1, 1, 5, 9$ radians.</p>	<p>(b)</p> <p>This plot shows a magnitude spectrum with twelve peaks, centered at $\omega = -9, -7, -5, -3, -1, 1, 3, 5, 7, 9$ radians. The peaks are narrower and taller than those in the original spectrum, reaching a maximum magnitude of approximately 5.3.</p>
<p>(c)</p> <p>This plot is identical to the original magnitude spectrum of $x[n]$, with six peaks at $\omega = -9, -5, -1, 1, 5, 9$ radians. The entire plot area is highlighted with a yellow background.</p>	<p>(d)</p> <p>This plot shows a magnitude spectrum with six peaks at $\omega = -9, -5, -1, 1, 5, 9$ radians. The y-axis scale is different, with major ticks at 1, 1.5, and 2. The peaks reach a maximum magnitude of approximately 2.6.</p>
<p>(e) None of the above</p>	