

GATE 2022 BM 14 Q

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Question: $x(t)$ is a real continuous-time signal whose magnitude frequency response $|X(j\Omega)|$ is shown below. After sampling $x(t)$ at 100 rad.s^{-1} , the spectral point P is down-converted to _____ rad.s^{-1} in the spectrum of the sampled signal.
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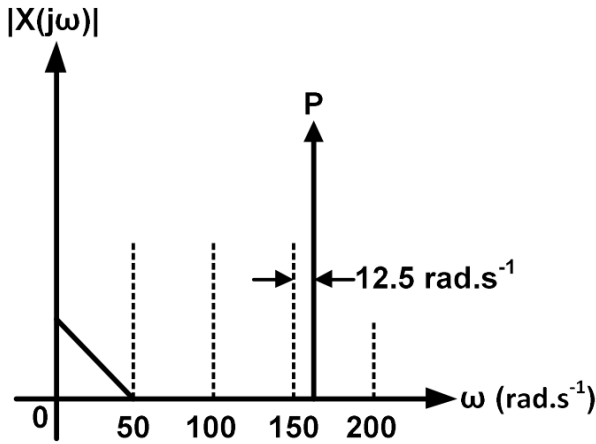


Fig. 1: Plot of $|X(j\omega)|$

Solution:

| Parameter | Description |
|-----------|-----------------------------------|
| $w(t)$ | Sampling Function |
| $W(s)$ | Fourier Transform of $w(t)$ |
| $x(t)$ | Input Signal |
| $X(s)$ | Input Signal Frequency Spectrum |
| $x_s(t)$ | Sampled Input Signal |
| $X_s(s)$ | Sampled Signal Frequency Spectrum |

TABLE 1: Table of parameters

The sampling function is:

$$w(t) = \sum_{k=-\infty}^{\infty} \delta\left(t - \frac{2\pi k}{100}\right) \quad (1)$$

$$W(j\omega) = 100 \sum_{k=-\infty}^{\infty} \delta(j(\omega - 100k)) \quad (2)$$

then the sampled function:

$$x_s(t) = x(t) w(t) \quad (3)$$

$$X_s(j\omega) = X(j\omega) * W(j\omega) \quad (4)$$

$$X_s(j\omega) = \int_{-\infty}^{\infty} X(j\theta) W(j(\omega - \theta)) d\theta \quad (5)$$

$$X_s(j\omega) = 100 \sum_{k=-\infty}^{\infty} \int_{-\infty}^{\infty} X(j\theta) \delta(j(\omega - 100k - \theta)) d\theta \quad (6)$$

$$X_s(j\omega) = 100 \sum_{k=-\infty}^{\infty} X(j(\omega - 100k)) \quad (7)$$

Thus, The down sampled point is at:

$$\omega = |162.5 - 100k| \quad (8)$$

where k is the nearest integer to $\frac{162.5}{100}$, which is 2
Thus,

$$\omega = 37.5 \text{ rad s}^{-1} \quad (9)$$

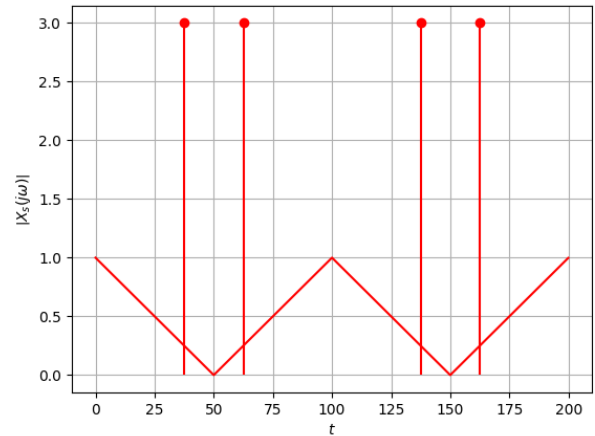


Fig. 2: Plot of $|X_s(j\omega)|$