BSM307
İşaretler ve Sistemler

Dr. Seçkin Arı

Örnekleme

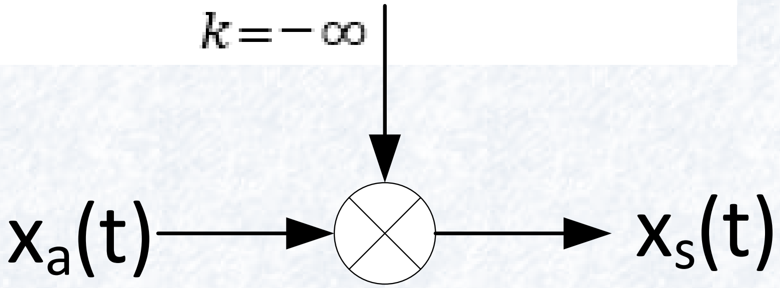
İçerik

- Örneklenmiş Sürekli Zaman İşaret
- Örneklenmiş İşaretin Frekans Spektrumu
- Nyquist Kriteri
- Örneklenmiş Ayrık Zaman İşaret

Örneklenmiş Sürekli Zaman İşaret

- İdeal örnekleme: Zamanda çarpma işlemi
  - ♦ $s(t) = \sum_{k=-\infty}^{\infty} \delta(t - kT_s)$: Darbe dizisi
  - ♦ T_s: Örnekleme Periyodu
- $x_s(t) = x_a(t)s(t)$

$$s(t) = \sum_{k=-\infty}^{\infty} \delta(t - kT_s)$$



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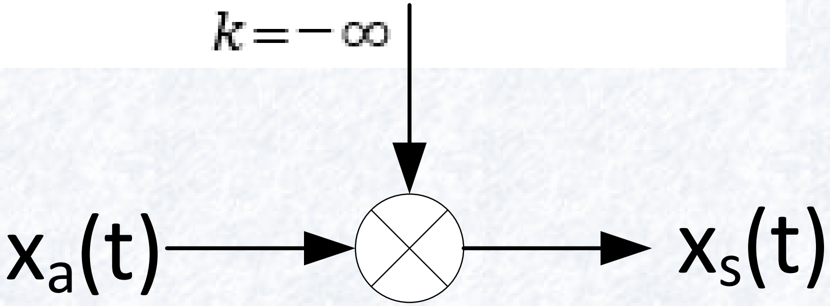

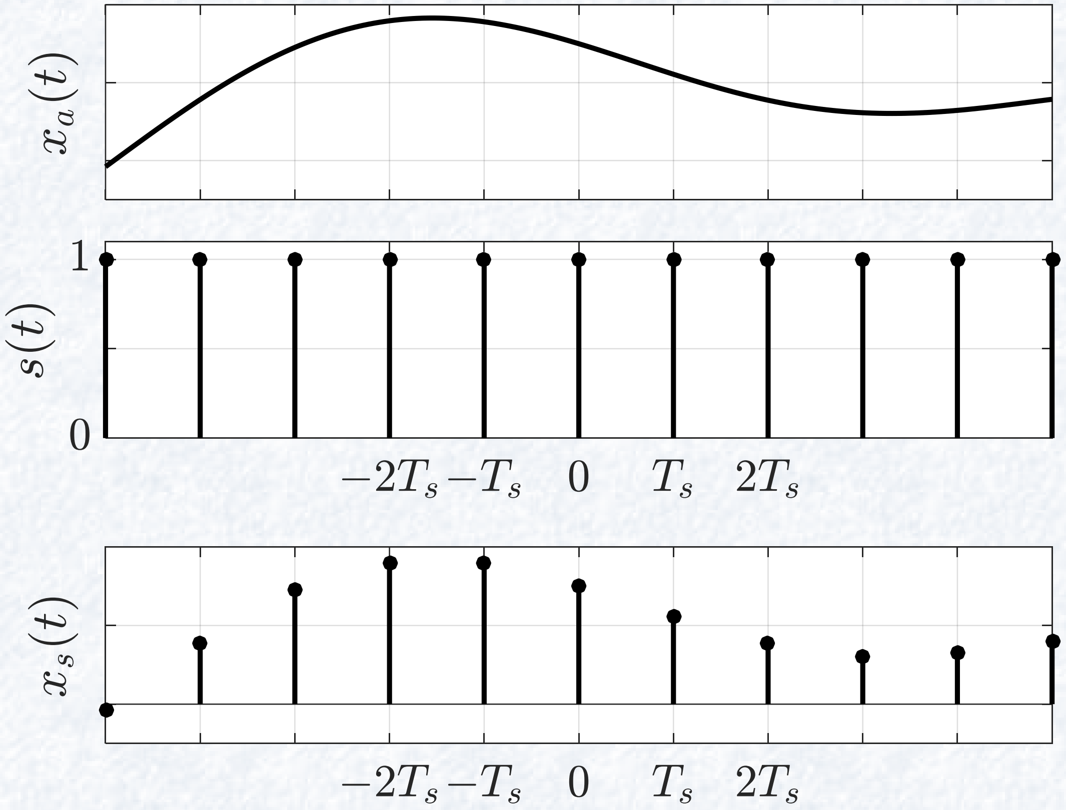

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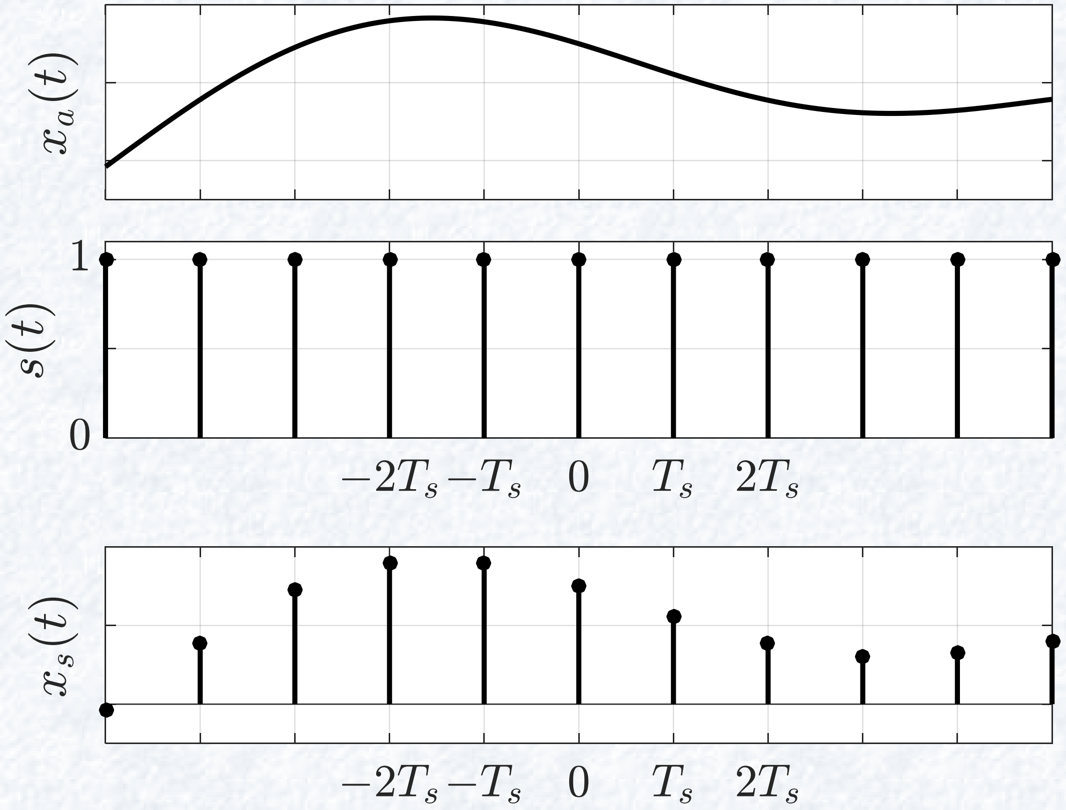

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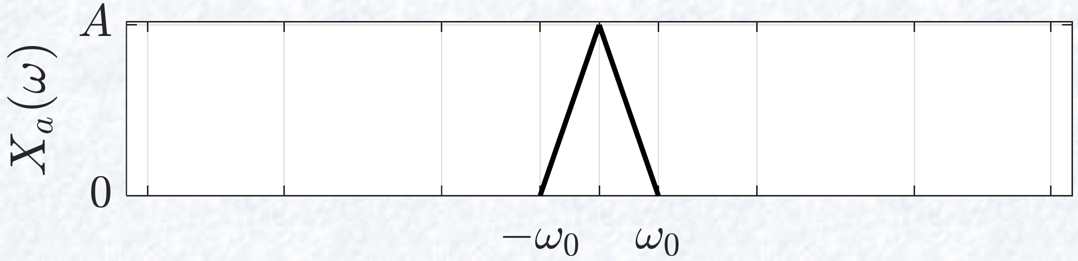

- $x_s(t) = x_a(t)s(t)$
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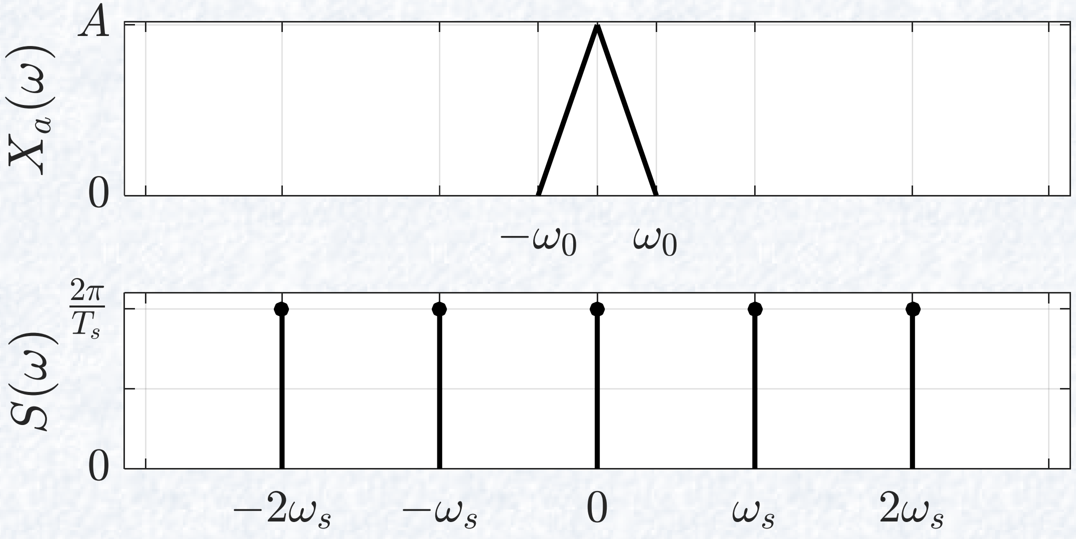

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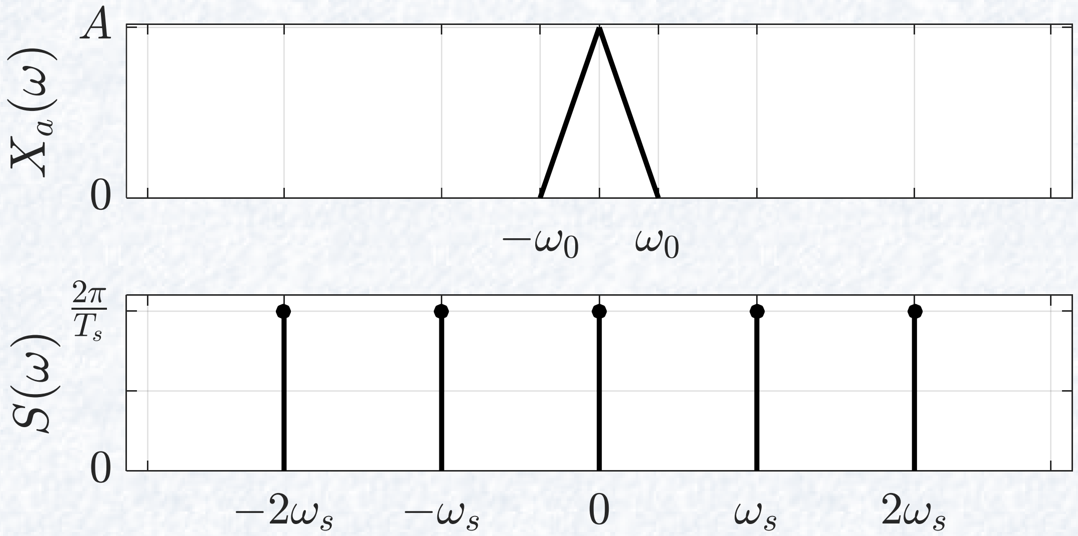

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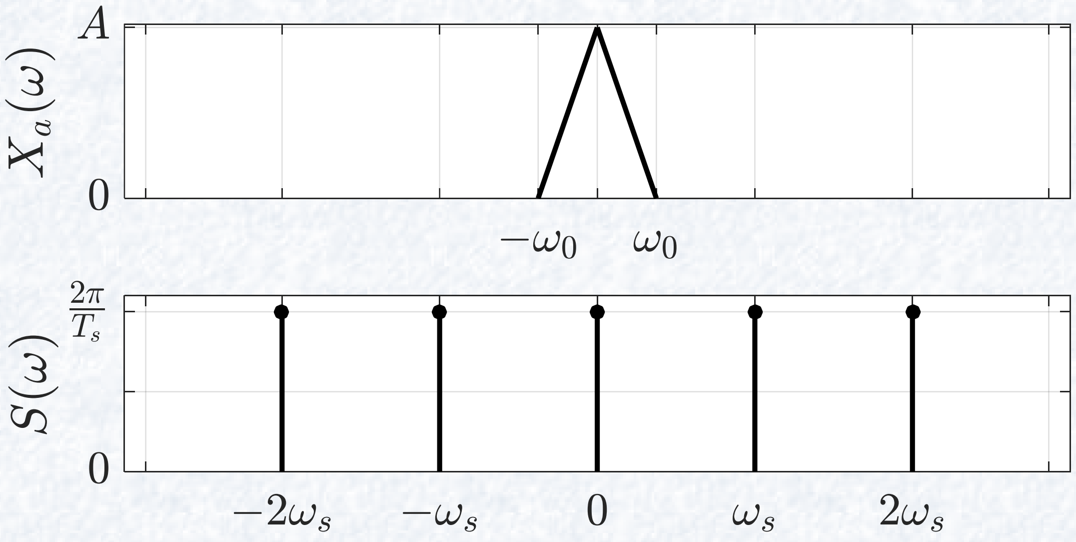

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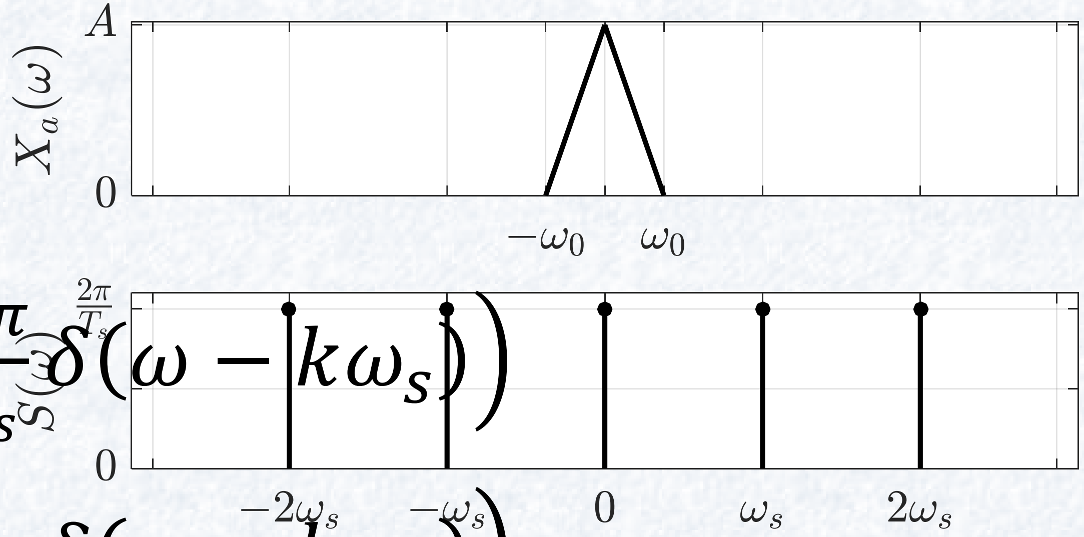

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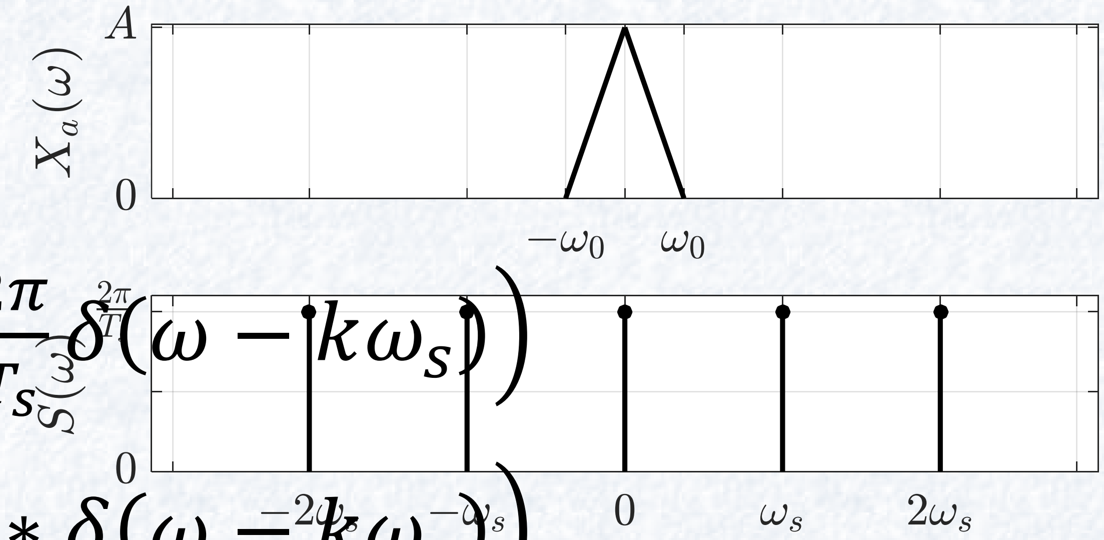

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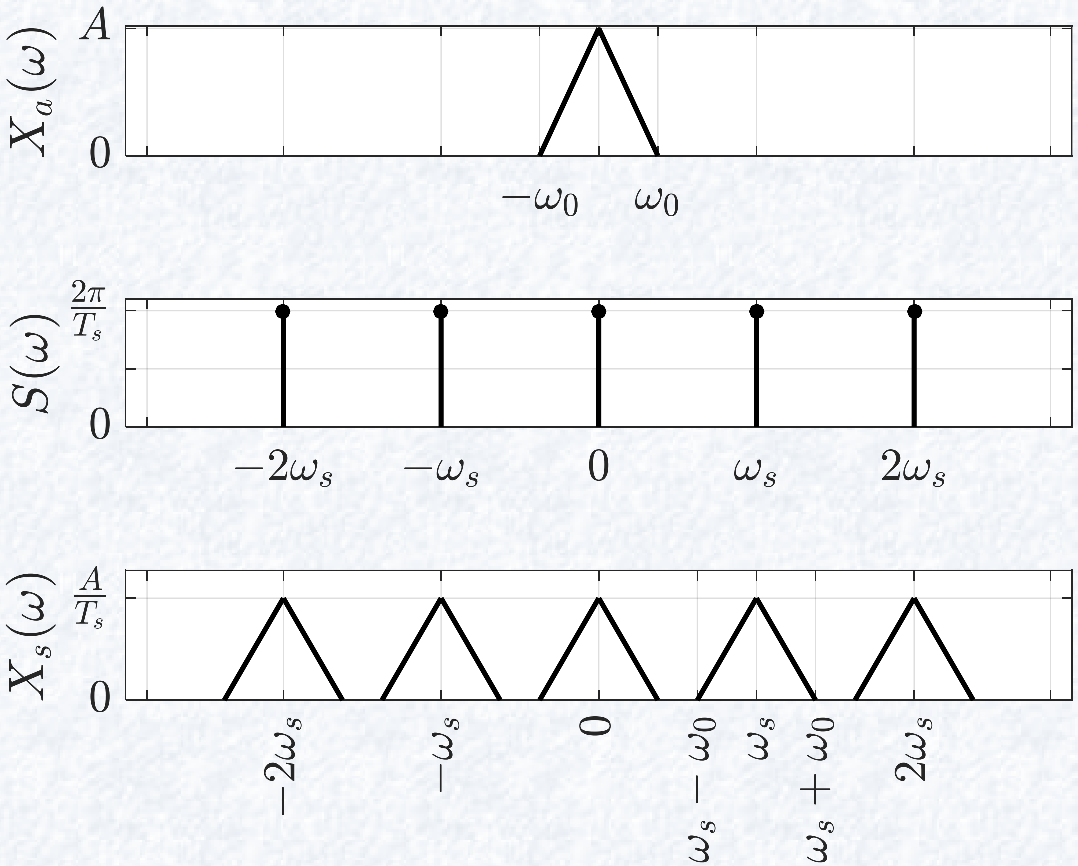

Nyquist Kriteri

- $X_s(\omega) = \frac{1}{2\pi}\left(X_a(\omega) * S(\omega)\right)$
- $S(\omega) = \sum_{k=-\infty}^{\infty} \frac{2\pi}{T_s}\delta(\omega - k\omega_s)$
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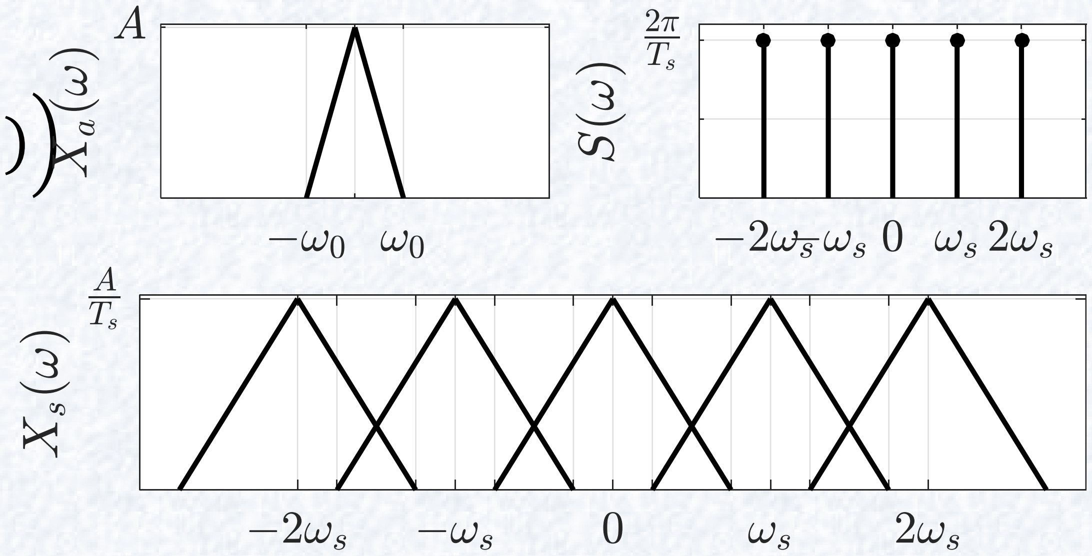

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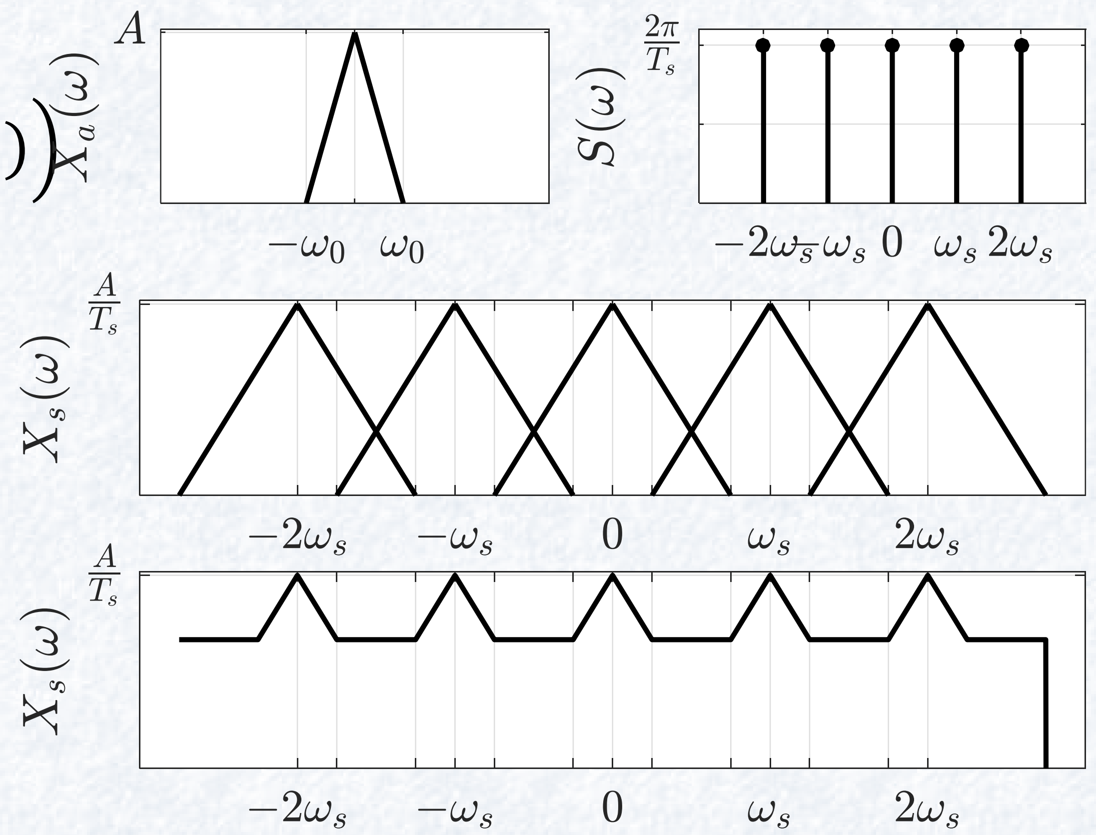
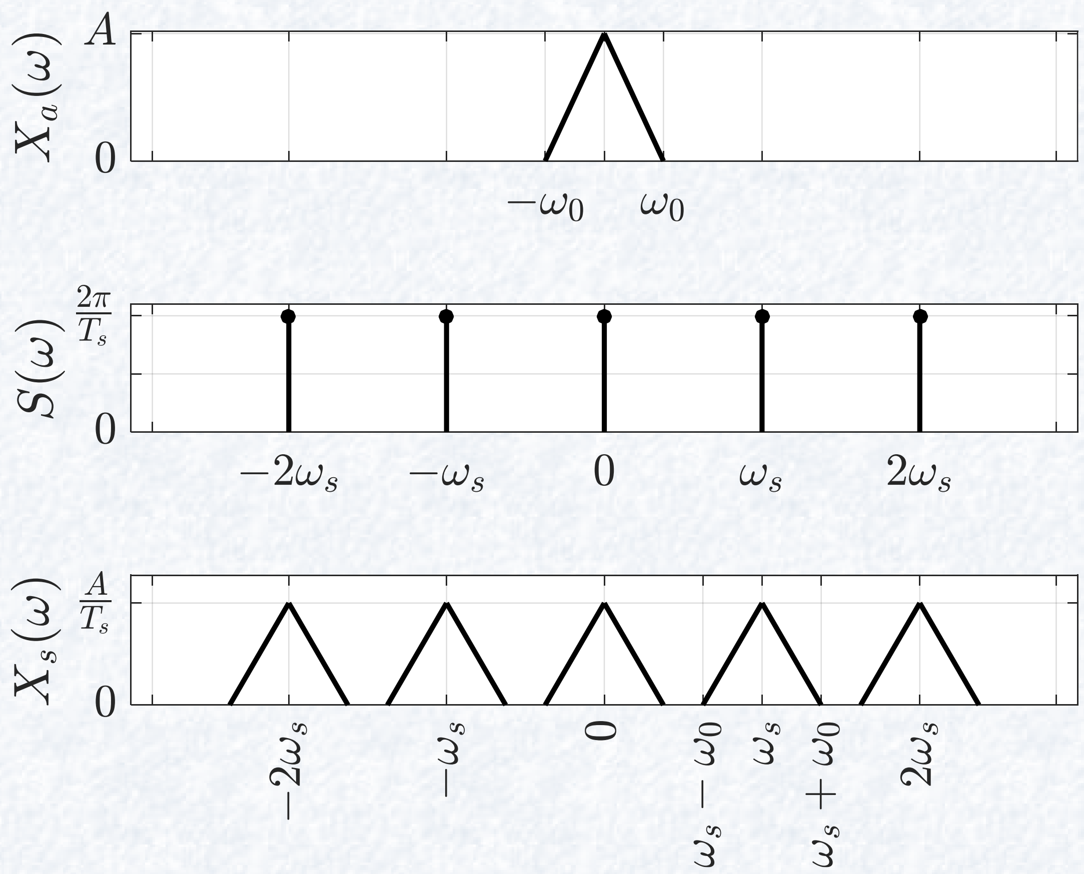
- $X_s(\omega) = \frac{1}{2\pi}\left(X_a(\omega) * \sum_{k=-\infty}^{\infty} \frac{2\pi}{T_s} \delta(\omega - k\omega_s)\right)$
- $X_s(\omega) = \frac{1}{T_s}\left(\sum_{k=-\infty}^{\infty} X_a(\omega - k\omega_s)\right)$
- Orijinal işaret geri dönülmez bir şekilde bozulmuştur.



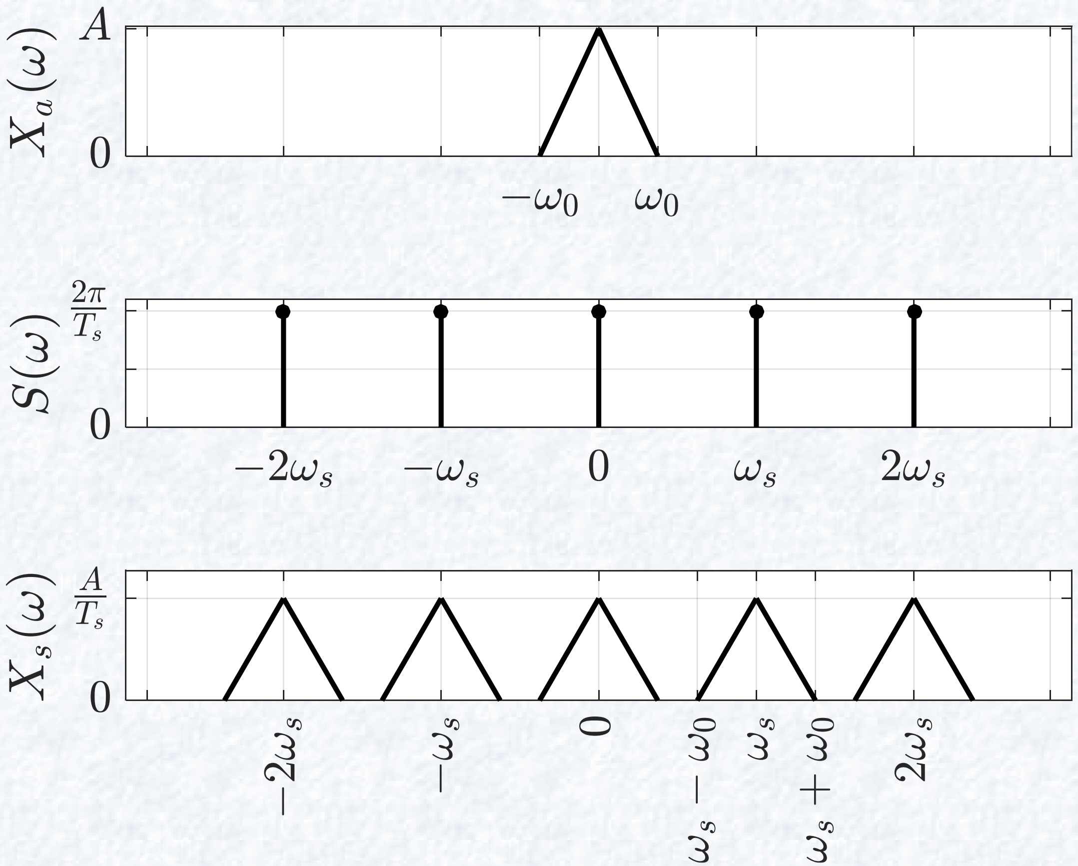
Nyquist Kriteri

- $\omega_s - \omega_0 > \omega_0$



Nyquist Kriteri

- $\omega_s - \omega_0 > \omega_0 \;\rightarrow \omega_s > 2\omega_0$



Ayrık Zaman İşaret

- $x(n) = x_a(nT_s)$

Örnek 1

- $x_a(t) = e^{j\omega_0 t}$ T_s periyodla örnekleniyor ise $x(n) = ?$

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- $x_a(t) = e^{j\omega_0 t}$, T_s periyodla örnekleniyor ise $x(n) =?$
- $x(n) = x_a(nT_s) = e^{j\omega_0 n T_s}$

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- $x_a(t) = e^{j\omega_0 t}$, T_s periyodla örnekleniyor ise $x(n) =?$
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- $x(n)$, periyodik midir?

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- $x(n)$, periyodik midir?
- $x(n) = x(n+N)$

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- $e^{j\omega_0 n T_s} =$

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- $e^{j2\pi k} = e^{j\omega_0 NT_s}$

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- $2\pi k = \omega_0 NT_s$

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- $e^{j2\pi k} = e^{j\omega_0 NT_s}$
- $2\pi k = \omega_0 NT_s = \frac{2\pi}{T_0} NT_s$

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- $1 = e^{j\omega_0 NT_s}$
- $e^{j2\pi k} = e^{j\omega_0 NT_s}$
- $2\pi k = \omega_0 NT_s = \frac{2\pi}{T_0} NT_s \rightarrow N = \frac{T_0}{T_s} k$

Örnek 2

- $x_a(t) = \cos(15t)\ T_s = \frac{\pi}{10}$ sn. periyodla örnekleniyor ise $x(n) =?$

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- $x(n) = \cos(15nT_s) = \cos\left(15n\frac{\pi}{10}\right) = \cos\left(\frac{3\pi}{2}n\right)$
- $N =$

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- $N = \frac{T_0}{T_s}k = \frac{2\pi/_{15}}{\pi/_{10}}k$
  - ♦ $T_0 = \frac{2\pi}{\omega_0} = \frac{2\pi}{15}$ sn

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- $N = \frac{T_0}{T_s}k = \frac{2\pi/_{15}}{\pi/_{10}}k = \frac{4}{3}k \ \rightarrow N = 4$
  - ♦ $T_0 = \frac{2\pi}{\omega_0} = \frac{2\pi}{15}$ sn

Örnek 3

- $x_a(t) = e^{-\alpha t}u(t), T_s$ periyodla örnekleniyor ise $x(n) =?$

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- $|z|$

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- $X(z) = \frac{1}{1-e^{-\alpha T_s}z^{-1}}$
- $|z| > e^{-\alpha T_s}$

Örnek 4

- $x(n) = \cos\left(\frac{\pi}{8}n\right)$ ve $f_s = 10k\mathrm{Hz}$ ise $x_a(t) =?$

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- $x_a(t) = \cos(\omega_0 t)$ olabilir.

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- $x_a(t) = \cos(\omega_0 t) = \cos(2\pi f_0 t)$
- $x(n) =$

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- $x(n) = \cos(2\pi f_0 n T_s) =$

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- $x_a(t) = \cos(\omega_0 t) = \cos(2\pi f_0 t)$
- $x(n) = \cos(2\pi f_0 n T_s) = \cos\left(2\pi f_0 n \frac{1}{f_s}\right) = \cos\left(\frac{\pi}{8}n\right)$
- $2\pi f_0 n \frac{1}{f_s} = \frac{\pi}{8}n \; \rightarrow f_0 =$

Örnek 4

- $x(n) = \cos\left(\frac{\pi}{8}n\right)$ ve $f_s = 10k\text{Hz}$ ise $x_a(t) =?$
- $x_a(t) = \cos(\omega_0 t) = \cos(2\pi f_0 t)$
- $x(n) = \cos(2\pi f_0 n T_s) = \cos\left(2\pi f_0 n \frac{1}{f_s}\right) = \cos\left(\frac{\pi}{8}n\right)$
- $2\pi f_0 n \frac{1}{f_s} = \frac{\pi}{8}n \rightarrow f_0 = \frac{\pi}{8}\frac{f_s}{2\pi} = \frac{f_s}{16} = 625\text{Hz}$

Örnek 4

- $x(n) = \cos\left(\frac{\pi}{8}n\right)$ ve $f_s = 10k\text{Hz}$ ise $x_a(t) =?$
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- $2\pi f_0 n \frac{1}{f_s} = \frac{\pi}{8}n \rightarrow f_0 = \frac{\pi}{8}\frac{f_s}{2\pi} = \frac{f_s}{16} = 625\text{Hz}$
- $x_a(t) = \cos(1250\pi t)$
- Başka bir $x_a(t)$ var mıdır?

Örnek 4

- $x(n) = \cos\left(\frac{\pi}{8}n\right)$ ve $f_s = 10k\text{Hz}$ ise $x_a(t) =?$
- $x_a(t) = \cos(\omega_0 t) = \cos(2\pi f_0 t)$
- $x(n) = \cos\left(2\pi f_0 n \frac{1}{f_s}\right) = \cos\left(2\pi f_0 n \frac{1}{f_s} \pm \square\right)$

Örnek 4

- $x(n) = \cos\left(\frac{\pi}{8}n\right)$ ve $f_s = 10k\mathrm{Hz}$ ise $x_a(t) =?$
- $x_a(t) = \cos(\omega_0 t) = \cos(2\pi f_0 t)$
- $x(n) = \cos\left(2\pi f_0 n \frac{1}{f_s}\right) = \cos\left(2\pi f_0 n \frac{1}{f_s} \pm 2\pi k n\right)$

Örnek 4

- $x(n) = \cos\left(\frac{\pi}{8}n\right)$ ve $f_s = 10k\text{Hz}$ ise $x_a(t) =?$
- $x_a(t) = \cos(\omega_0 t) = \cos(2\pi f_0 t)$
- $x(n) = \cos\left(2\pi f_0 n \frac{1}{f_s}\right) = \cos\left(2\pi f_0 n \frac{1}{f_s} \pm 2\pi k n \times 1\right)$

Örnek 4

- $x(n) = \cos\left(\frac{\pi}{8}n\right)$ ve $f_s = 10k\text{Hz}$ ise $x_a(t) =?$
- $x_a(t) = \cos(\omega_0 t) = \cos(2\pi f_0 t)$
- $x(n) = \cos\left(2\pi f_0 n \frac{1}{f_s}\right) = \cos\left(2\pi f_0 n \frac{1}{f_s} \pm 2\pi k n \frac{f_s}{f_s}\right)$
- $x(n) =$

Örnek 4

- $x(n) = \cos\left(\frac{\pi}{8}n\right)$ ve $f_s = 10k\mathrm{Hz}$ ise $x_a(t) =?$
- $x_a(t) = \cos(\omega_0 t) = \cos(2\pi f_0 t)$
- $x(n) = \cos\left(2\pi f_0 n \frac{1}{f_s}\right) = \cos\left(2\pi f_0 n \frac{1}{f_s} \pm 2\pi k n \frac{f_s}{f_s}\right)$
- $x(n) = \cos\left(2\pi n \left(\frac{f_0}{f_s} \pm k \frac{f_s}{f_s}\right)\right)$

Örnek 4

- $x(n) = \cos\left(\frac{\pi}{8}n\right)$ ve $f_s = 10k\text{Hz}$ ise $x_a(t) =?$
- $x_a(t) = \cos(\omega_0 t) = \cos(2\pi f_0 t)$
- $x(n) = \cos\left(2\pi f_0 n \frac{1}{f_s}\right) = \cos\left(2\pi f_0 n \frac{1}{f_s} \pm 2\pi k n \frac{f_s}{f_s}\right)$
- $x(n) = \cos\left(2\pi n \left(\frac{f_0}{f_s} \pm k \frac{f_s}{f_s}\right)\right) = \cos\left(\frac{\pi}{8}n\right)$

Örnek 4

- $x(n) = \cos\left(\frac{\pi}{8}n\right)$ ve $f_s = 10k\text{Hz}$ ise $x_a(t) =?$
- $x_a(t) = \cos(\omega_0 t) = \cos(2\pi f_0 t)$
- $x(n) = \cos\left(2\pi f_0 n \frac{1}{f_s}\right) = \cos\left(2\pi f_0 n \frac{1}{f_s} \pm 2\pi k n \frac{f_s}{f_s}\right)$
- $x(n) = \cos\left(2\pi n \left(\frac{f_0}{f_s} \pm k \frac{f_s}{f_s}\right)\right) = \cos\left(\frac{\pi}{8}n\right)$
- $2\pi n \left(\frac{f_0}{f_s} \pm k \frac{f_s}{f_s}\right) = \frac{\pi}{8}n$

Örnek 4

- $x(n) = \cos\left(\frac{\pi}{8}n\right)$ ve $f_s = 10k\text{Hz}$ ise $x_a(t) = ?$
- $x_a(t) = \cos(\omega_0 t) = \cos(2\pi f_0 t)$
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- $2\pi n\left(\frac{f_0}{f_s} \pm k\frac{f_s}{f_s}\right) = \frac{\pi}{8}n$
  - $k = -1$ için $\frac{f_0 - f_s}{f_s} = \frac{1}{16} \rightarrow f_0 =$

Örnek 4

- $x(n) = \cos\left(\frac{\pi}{8}n\right)$ ve $f_s = 10k\text{Hz}$ ise $x_a(t) = ?$
- $x_a(t) = \cos(\omega_0 t) = \cos(2\pi f_0 t)$
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- $2\pi n \left(\frac{f_0}{f_s} \pm k \frac{f_s}{f_s}\right) = \frac{\pi}{8}n$
  - $k = -1$ için $\frac{f_0 - f_s}{f_s} = \frac{1}{16} \rightarrow f_0 = \frac{f_s}{16} + f_s = 10625\text{Hz}$
  - $x_a(t) = \cos(21250\pi t)$

Örnek 5

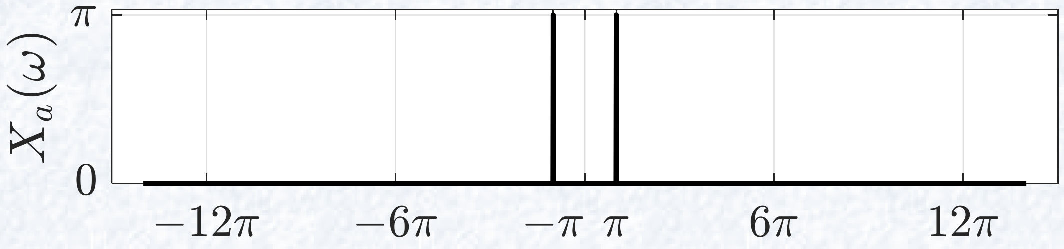
- $x_a(t) = \cos(\omega_0 t), T_s = \frac{1}{3}$ sn. ile örnekleniyor.
- $\omega_0 = \pi$ rad/sn. için $X_s(\omega) =$?
- $\omega_s =$

Örnek 5

- $x_a(t) = \cos(\omega_0 t), T_s = \frac{1}{3}$ sn. ile örnekleniyor.
- $\omega_0 = \pi$ rad/sn. için $X_s(\omega) =?$
- $\omega_s = \frac{2\pi}{T_s} = 6\pi$ rad/sn.
- $X_a(\omega) =$

Örnek 5

- $x_a(t) = \cos(\omega_0 t), T_s = \frac{1}{3}$ sn. ile örnekleniyor.
- $\omega_0 = \pi$ rad/sn. için $X_s(\omega) =?$
- $\omega_s = \frac{2\pi}{T_s} = 6\pi$ rad/sn.
- $X_a(\omega) = \pi\delta(\omega - \pi) + \pi\delta(\omega + \pi)$
- $S(\omega) =$



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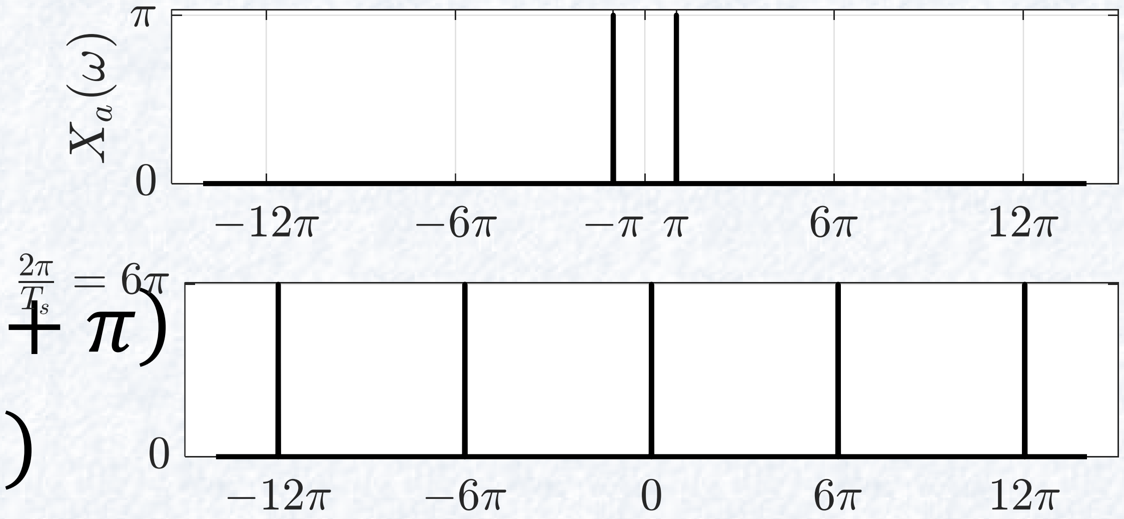
- $S(\omega) = \sum_{k=-\infty}^{\infty} 6\pi\delta(\omega - 6\pi k)$
- $X_s(\omega) =$



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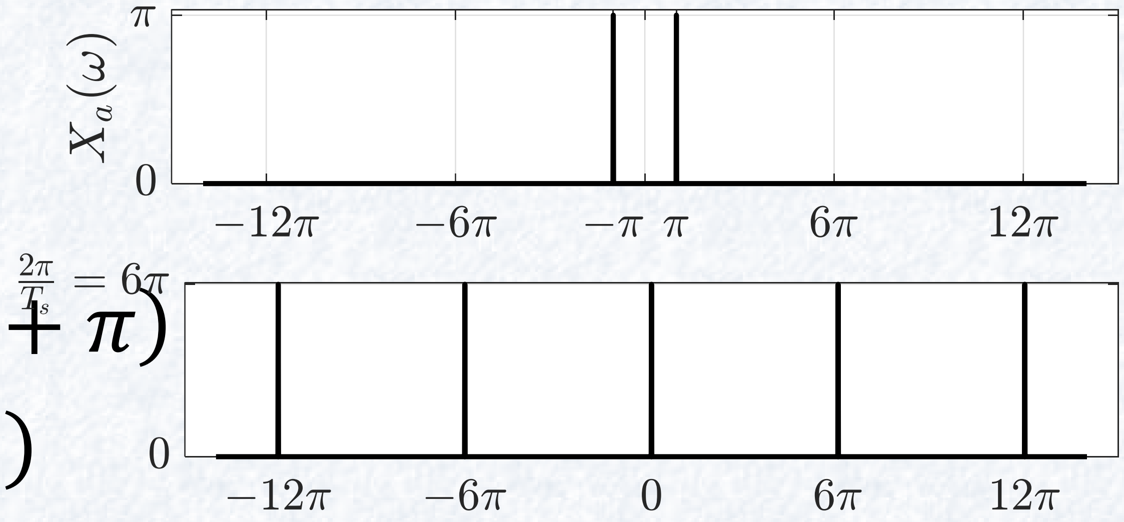
- $X_s(\omega) = \frac{1}{2\pi}\left(X_a(\omega) * S(\omega)\right)$



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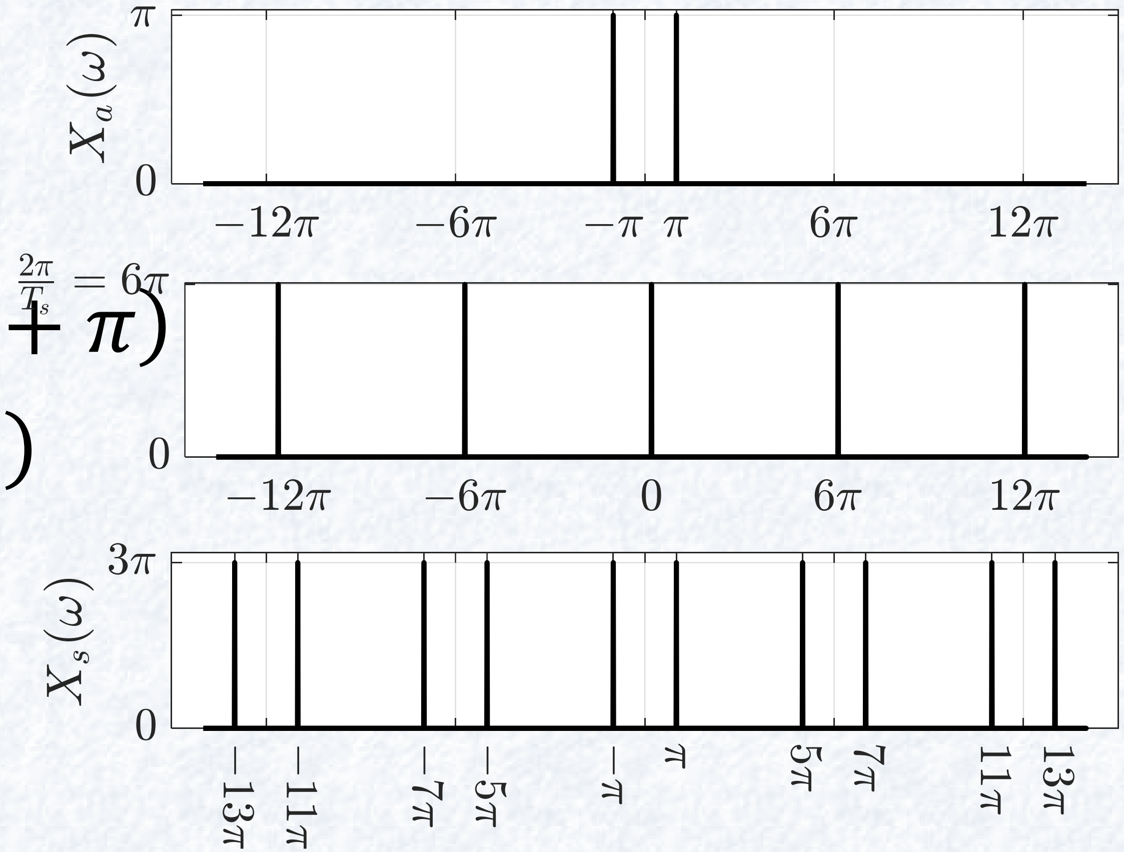

Örnek 5

- $x_a(t) = \cos(\omega_0 t), T_s = \frac{1}{3}$ sn. ile örnekleniyor.
- $\omega_0 = 2\pi$ rad/sn. için $X_s(\omega) =?$
- $\omega_s = \frac{2\pi}{T_s} = 6\pi$ rad/sn.
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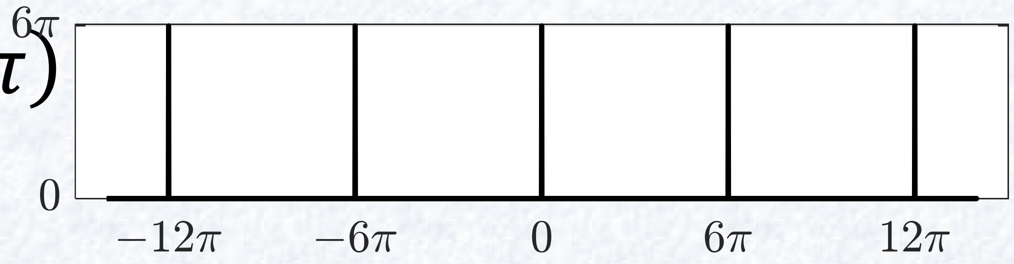

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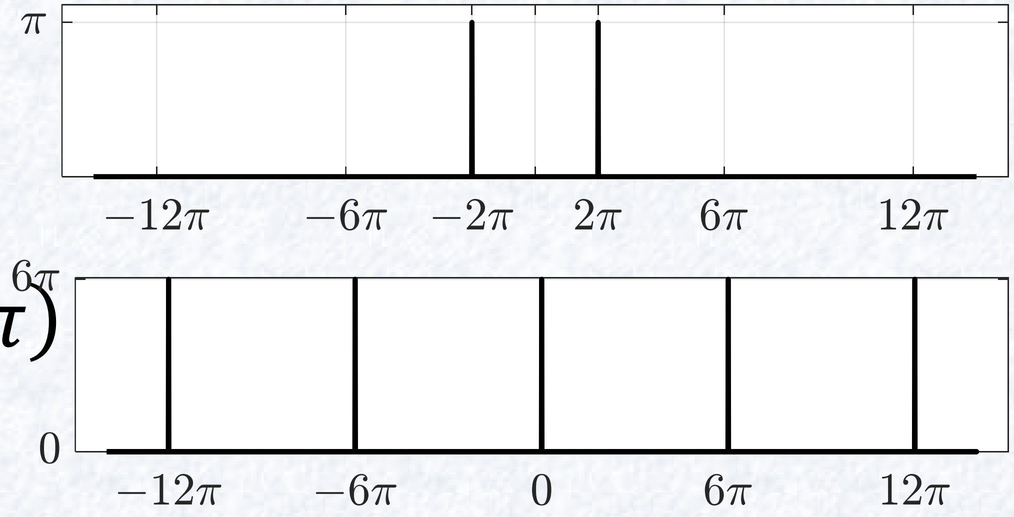

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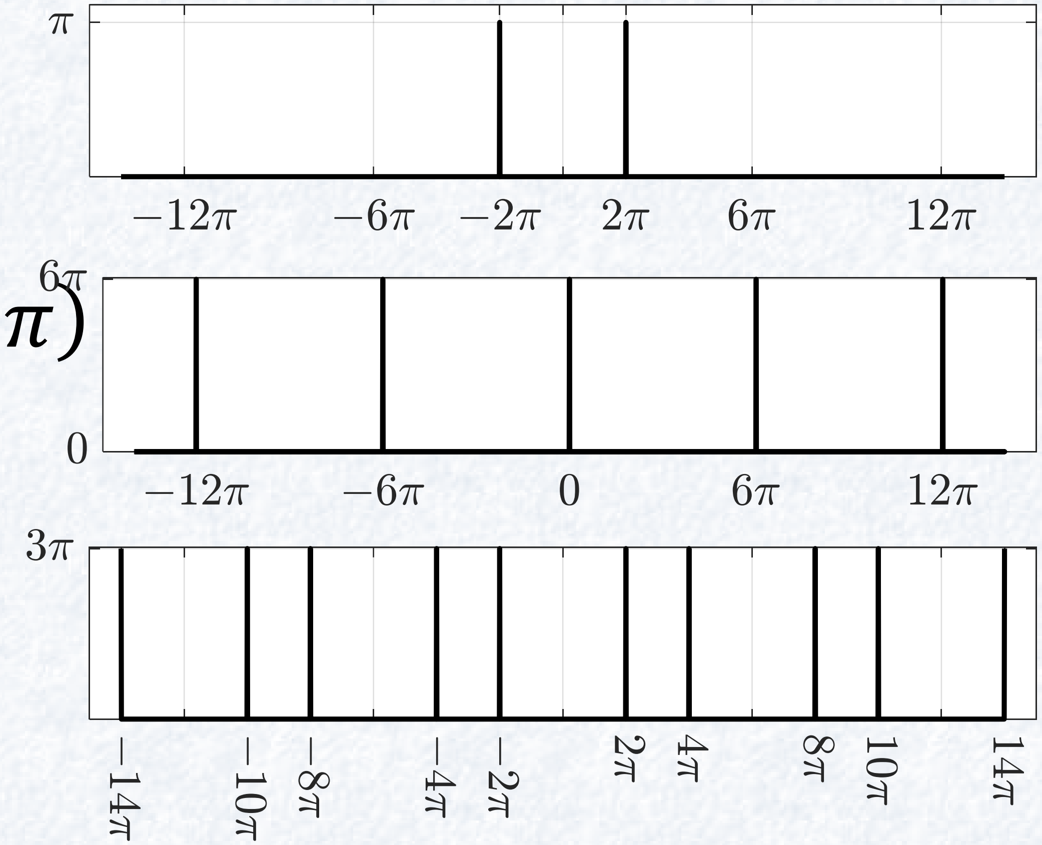

Örnek 5

- $x_a(t) = \cos(\omega_0 t), T_s = \frac{1}{3}$ sn. ile örnekleniyor.
- $\omega_0 = 5\pi$ rad/sn. için $X_s(\omega) = ?$
- $\omega_s = \frac{2\pi}{T_s} = 6\pi$ rad/sn.
- $X_a(\omega) = \pi\delta(\omega - \pi) + \pi\delta(\omega + \pi)$
- $S(\omega) = \sum_{k=-\infty}^{\infty} 6\pi\delta(\omega - 6\pi k)$
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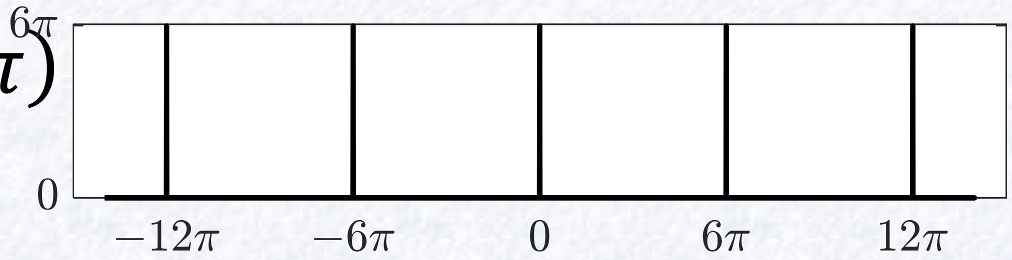

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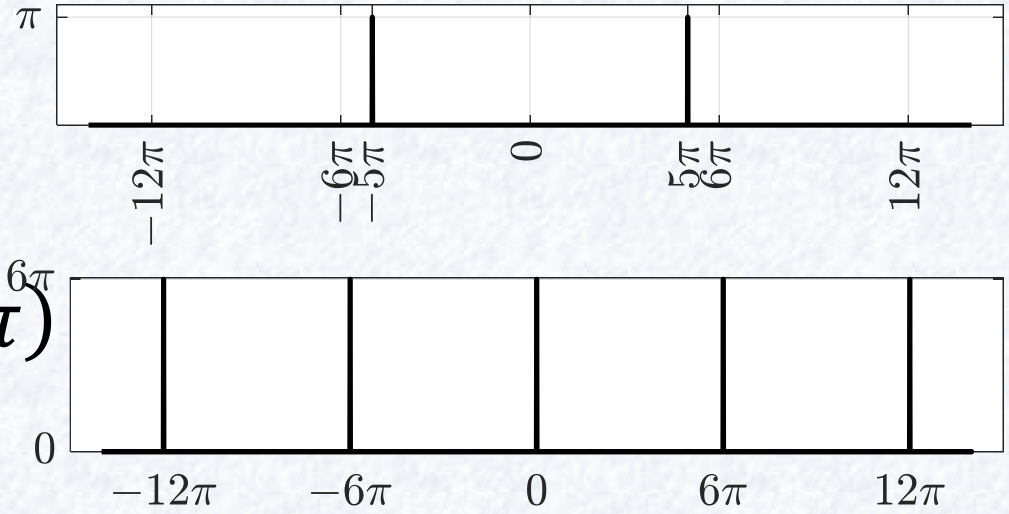

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