Sayısal Haberleşme

Örnekle-tut, PAM/PWM/PPM, TDM ve PCM

Orijinal not: ELM365-2024-Bahar-5-hafta-ders-notlari.pdf

UYARI Bu belge, el yazısı ders notlarından Claude (Anthropic) yardımıyla dijitale aktarılmıştır. Yardımcı kaynak olarak hazırlanmıştır; hata veya eksik içerebilir. Lütfen orijinal notları ve ders kaynaklarını esas alın.

NOTICE *This document was transcribed from handwritten lecture notes with the help of Claude (Anthropic). It is meant as a supplementary resource and may contain errors or omissions. Always check against the original notes and official course material.*

orj. s. 1

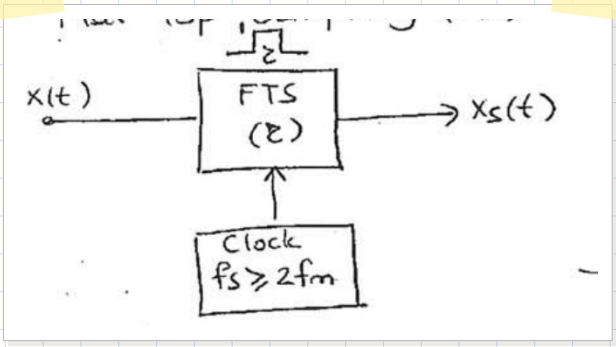
Sample and Hold Operation (Örnekle ve tut işlemi)

Flat Top Sampling (FTS)

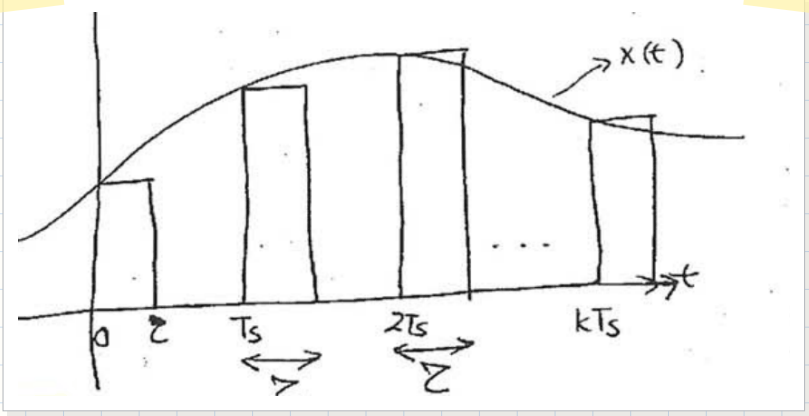
(Düz Tepeli Örnekleme)

Sample and Hold Operation

Flat Top Sampling (FTS)



orijinal çizim, s. 1

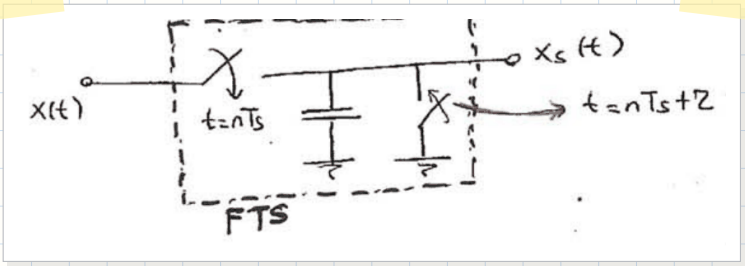


orijinal çizim, s. 1

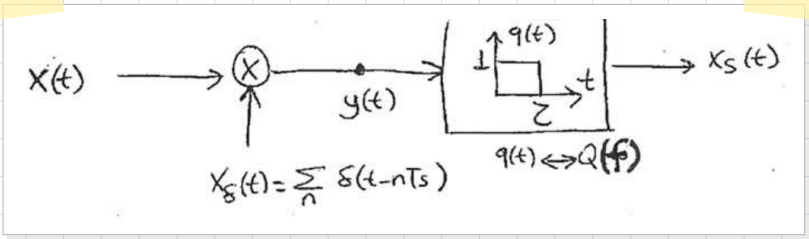
$x_s(t)$: Pulse Amplitude Modulation (PAM)

Discrete time analog modulation

Sample / Hold (Dump) circuit (Örnekle ve tut devresi)



orijinal çizim, s. 1



orijinal çizim, s. 1

orj. s. 2

$$y(t) = x(t)\,x_\delta(t) = \sum_n x(nT_s)\,\delta(t - nT_s)$$

$$x_s(t) = q(t) \circledast y(t) = \sum_n x(nT_s)\,q(t - nT_s)$$

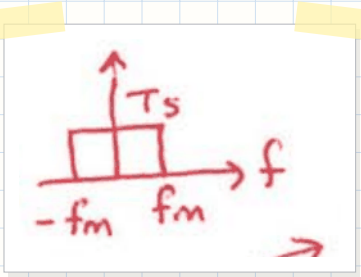
$$x_s(t) = q(t) \circledast \left[x(t)\,x_\delta(t)\right] = q(t) \circledast \left[\sum_n x(nT_s)\,\delta(t - nT_s)\right] = \sum_n x(nT_s)\,q(t - nT_s)$$

$$X_s(f) = Q(f) \cdot \left[X(f) \circledast X_\delta(f)\right] = Q(f) \cdot \left[X(f) \circledast f_s \sum_n \delta(f - nf_s)\right]$$

$$\boxed{X_s(f) = Q(f) \cdot \left[f_s \sum_n X(f - nf_s)\right]}$$

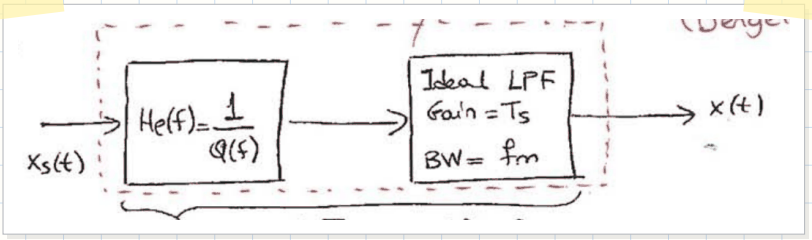
$$\hookrightarrow \tau\,\mathrm{sinc}(f\tau) \cdot e^{-j2\pi f\frac{\tau}{2}}$$

$$X_s(f) = \underbrace{f_s\,Q(f)\,X(f)}_{!} + Q(f) \cdot f_s \sum_{n\neq 0} X(f - nf_s)$$



orijinal çizim, s. 2

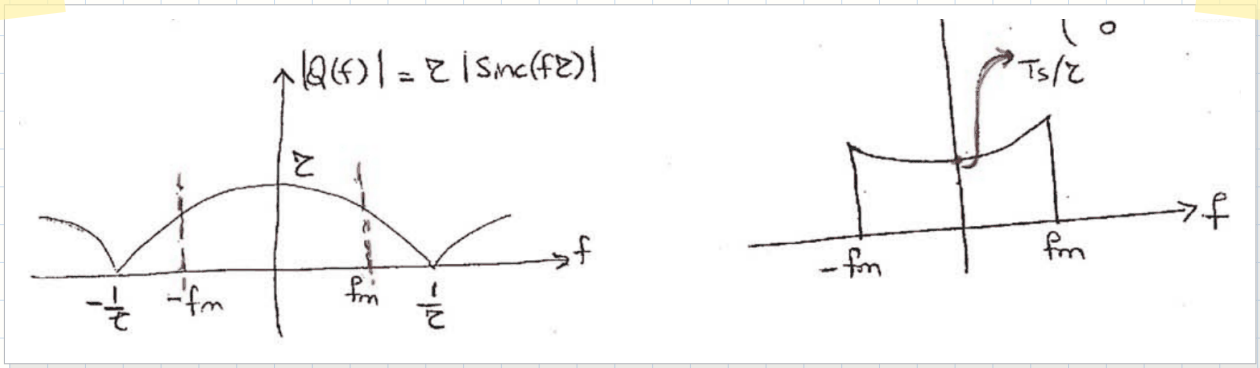
Equalizing LPF (Dengeleyici AGF)



orijinal çizim, s. 2

$$H_{eq}(f) = \begin{cases} \dfrac{T_s}{Q(f)} & |f| \le f_m \\ 0 & \text{else} \end{cases}$$

$$|H_{eq}(f)| = \begin{cases} \dfrac{T_s}{|Q(f)|} & |f| \le f_m \\ 0 & \text{else} \end{cases}$$



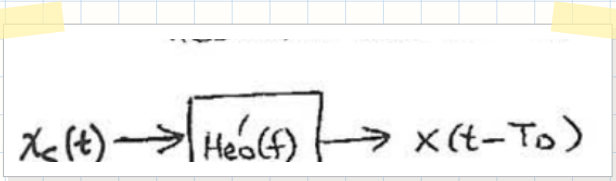
orijinal çizim, s. 2

$$H_{eq}(f) = \frac{T_s}{Q(f)} = \frac{T_s}{\tau\,\mathrm{sinc}(f\tau)}\, e^{j2\pi f\frac{\tau}{2}}, \qquad |f| \le f_m$$

↪ advance in time → $h_{eq}(t)$ is not causal

For this reason, $H'_{eq}(f) = H_{eq}(f) \cdot e^{-j2\pi f T_x}$ is chosen

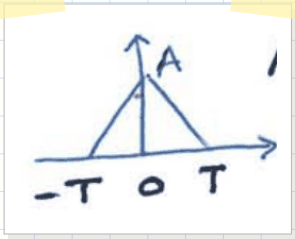
$$h'_{eq}(t) = h_{eq}(t - T_x) \qquad T_x = \frac{\tau}{2} + T_D$$



orijinal çizim, s. 2

orj. s. 3

Reminder:

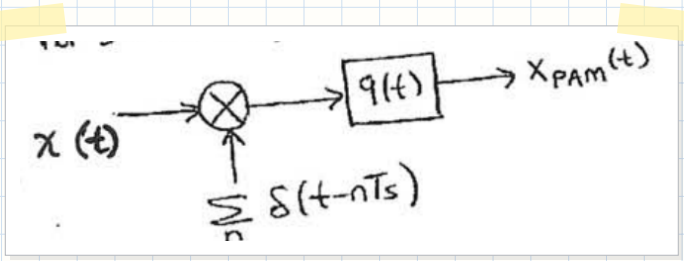


orijinal çizim, s. 3

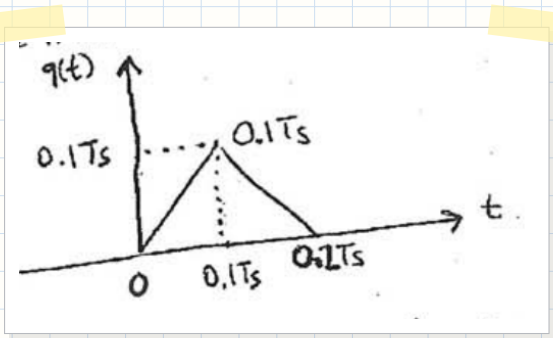
$$A \cdot \Lambda\left(\frac{t}{T}\right) \overset{F}{\longleftrightarrow} AT\,\mathrm{Sinc}^2(fT)$$

Örnek (2004 Midterm Ex. Q.)

A PAM signal is produced as shown in the figure below. a) If the bandwidth of $x(t)$ is 1 kHz, what is the maximum value of T_s to obtain $x(t)$ without distortion at the receiver? b) For $T_s = T_s(\max)$, sketch PAM demodulator. Find the transfer function of demodulator.



orijinal çizim, s. 3



orijinal çizim, s. 3

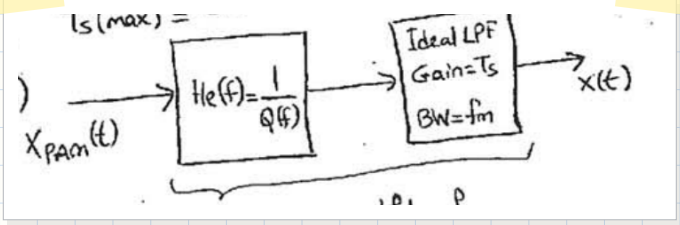
a) $BW\{x(t)\} = 1\ \text{kHz} = f_m$

$f_s \geq 2f_m = 2\ \text{kHz}$

$T_s \leq \dfrac{1}{2f_m} = 0.5\ \text{msec}$

$T_s(\max) = 0.5\ \text{msec}$

b)



orijinal çizim, s. 3

$$H_{eq}(f) = \begin{cases} \dfrac{T_s}{Q(f)} & |f| \le f_m \\ 0 & |f| > f_m \end{cases}$$

$$Q(f) = 0.1T_s \times 0.1T_s \,\mathrm{Sinc}^2(0.1T_s f)\, e^{-j2\pi f 0.1T_s}$$
$$= 0.01\,T_s^2 \,\mathrm{Sinc}^2(0.1T_s f)\, e^{-j2\pi f 0.1T_s}$$

$$H_{eq}(f) = \frac{T_s\, e^{+j2\pi f 0.1T_s}}{0.01\,T_s^2 \,\mathrm{Sinc}^2(0.1T_s f)}$$

$$= \begin{cases} \dfrac{2\times 10^5\, e^{j2\pi f 5\times 10^{-5}}}{\mathrm{Sinc}^2(5\times 10^{-5} f)} & |f| \le 1\ \mathrm{kHz} \\ 0 & \text{else} \end{cases}$$

orj. s. 4

> *Şekil:* Bu sayfa basılı materyal içeriyor (ör. ders slaytı); dijitalleştirilmedi. (Basılı şekil: PAM, PWM ve PPM dalga biçimleri.)
> *(orijinal notta, s. 4)*

PAM

PWM: Pulse Width Modulation (Darbe Genişlik Modülasyonu)

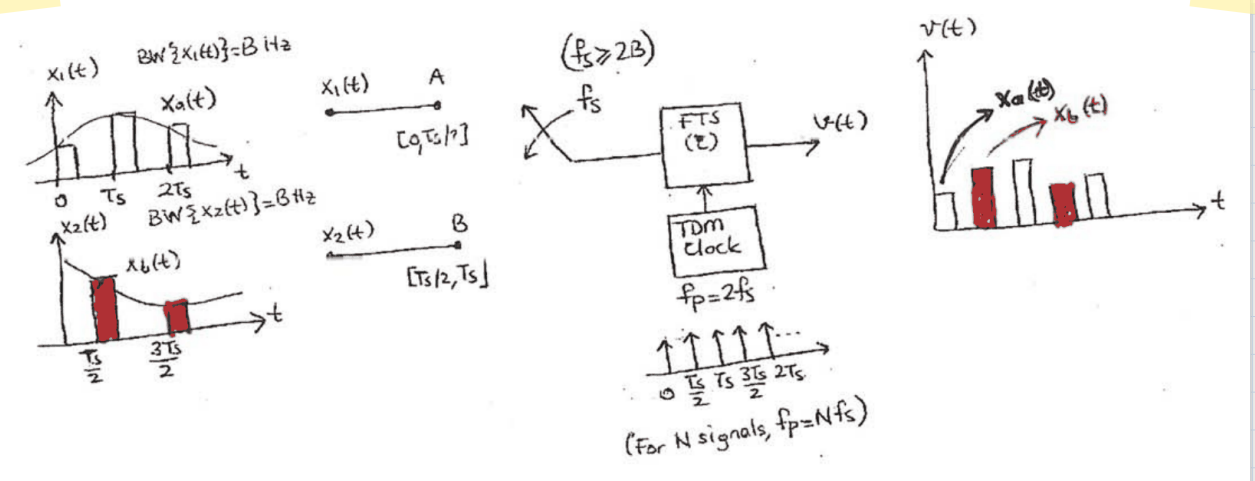
PPM: Pulse Position Modulation (Darbe Pozisyon Modülasyonu)

orj. s. 5

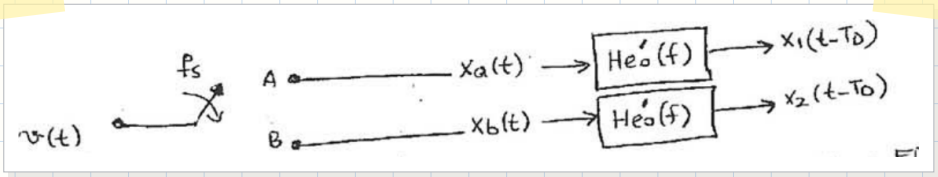
Time Division Multiplexing (TDM)

Zaman Bölmeli Çoklama (ZBÇ)

- Multiple PAM signals are transmitted without overlapping.
- At the receiver, PAM signals are separated by synchronization.



orijinal çizim, s. 5



orijinal çizim, s. 5

FDM x TDM

Advantages: 1) Easier to implement. 2) Less crosstalk than FDM

Disadvantages: 1) strict synchronization

Çok kaynaklı (Multi-source) ⟶ Multiplexing (Çoklama)

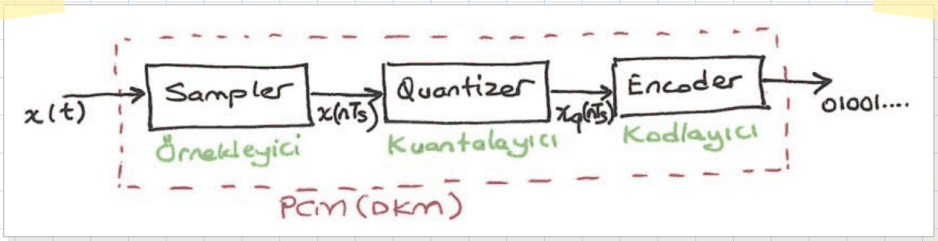
Çok kullanıcılı (Multi-user) ⟶ Multiple Access (Çoklu Erişim)

↪ TDMA, FDMA

orj. s. 6

Pulse Code Modulation (PCM)

(Darbe Kod Modülasyonu - DKM)



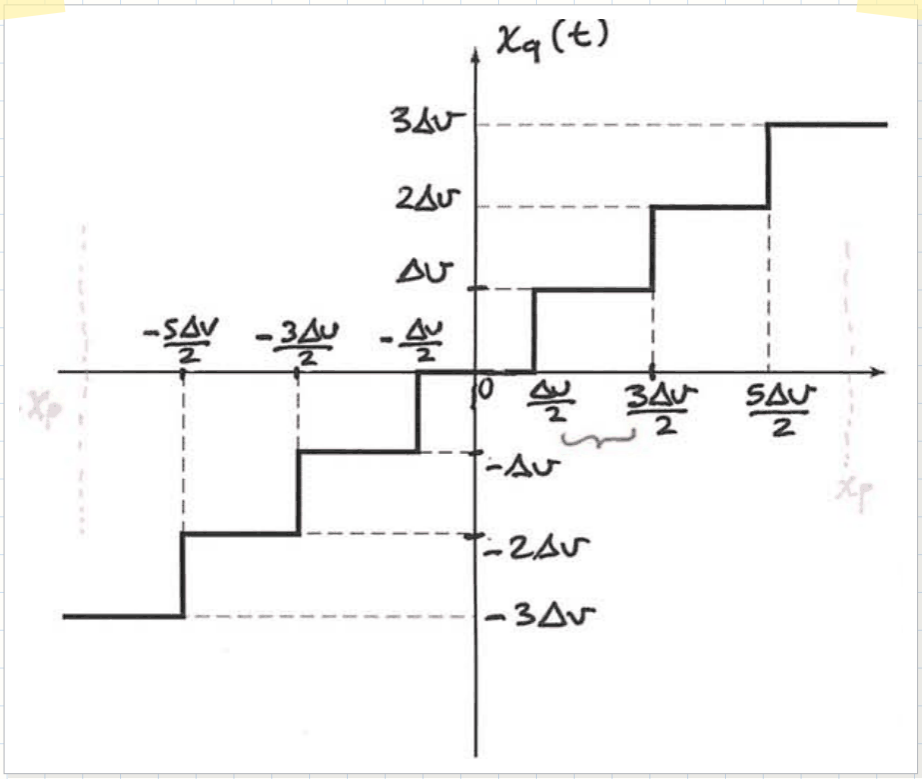
orijinal çizim, s. 6

$x(t)$ analog signal

$x_p = \text{maks}\,|x(t)|$ Peak value (Tepe değer)

Kuantalayıcı adımı = $\Delta v = \frac{2x_p}{L}$ ⟶ Kuantalayıcıdaki seviye sayısı (# of levels in quantizer)

(Quantizer step)

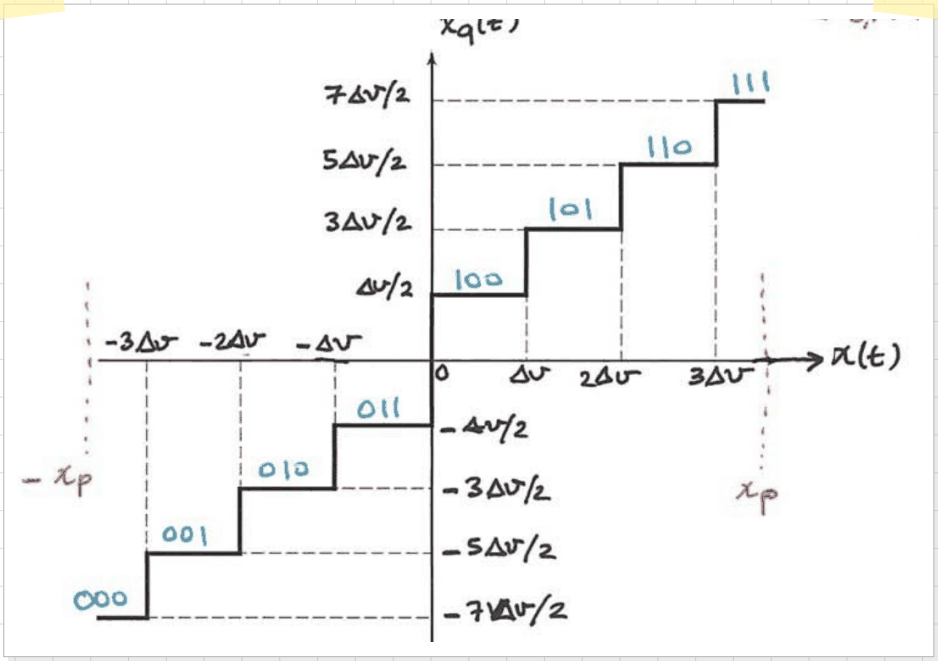


orijinal çizim, s. 6

$L = 7$

Assume $\Delta v = 1$ V

$x(t)$		$x_q(t)$
1,03 V	⟶	1 V
1,40 V	⟶	1 V
0,55 V	⟶	1 V
2,25 V	⟶	2 V
−3,1 V	⟶	−3 V



orijinal çizim, s. 6

$L = 8$ (mid-rise quantizer)

Assume $\Delta v = 1$ V

$x(t)$	$x_q(t)$
1,03 V	1,5 V
0,55 V	0,5 V
−3,1 V	−3,5 V

* Each sample is approximated with a quantized value, the approximation will result in an error less than $\Delta v/2$ in the positive direction or $-\Delta v/2$ in the negative ? direction

∴ Quantization error range: $(-\Delta v/2,\ \Delta v/2)$

orj. s. 7

Kuantalama gürültüsü (Quantization noise)

$$\underbrace{x_q(t)}_{\text{Kuantalanmış işaret}} = \underbrace{x(t)}_{\text{Analog işaret}} + \overbrace{q(t)}$$

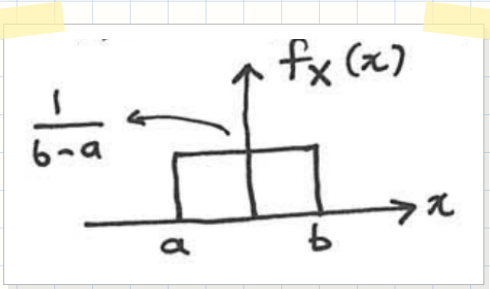
q is uniform in $[-\Delta v/2,\ \Delta v/2]$

Average quantization noise power = $N_q = E[q^2]$

(Ort. kuantalama gürültüsü gücü)

Reminder

X, RD $[a, b]$ düzgün d.



orijinal çizim, s. 7

$$\mu_x = \frac{a+b}{2} \qquad \sigma_x^2 = \frac{(b-a)^2}{12}$$

$$\sigma_q^2 = E\left[(q - \underbrace{\mu_q}_{0})^2\right] = E[q^2] = N_q$$

$$N_q = \frac{[\Delta v/2 - (-\Delta v/2)]^2}{12} = \frac{\Delta v^2}{12}$$

$$\Delta v = \frac{2x_p}{L} \longrightarrow \boxed{N_q = \frac{\Delta v^2}{12} = \frac{x_p^2}{3L^2}}$$

İşaretin gücü = $S_o = \langle x^2(t) \rangle = P_x$

Gürültünün gücü = $N_o = N_q$

İşaretin Gürültüye Oranı (İGO)
Signal-to-Noise Ratio (SNR)

$$\boxed{SNR = \frac{S_o}{N_o} = \frac{P_x}{x_p^2} \cdot 3L^2}$$

↪ Signal-to-Quantization Noise Ratio (SQNR)

> *Şekil:* Bu sayfa basılı materyal içeriyor (ör. ders slaytı); dijitalleştirilmedi. (Basılı şekil ve tablo: kuantalama aralıkları, doğal/kuantalanmış örnek değerleri, kod numaraları ve PCM dizisi.)
> *(orijinal notta, s. 7)*

Quantization intervals

* Each sample is quantized to the middle of the quantization interval.