



BSM307

İşaretler ve Sistemler

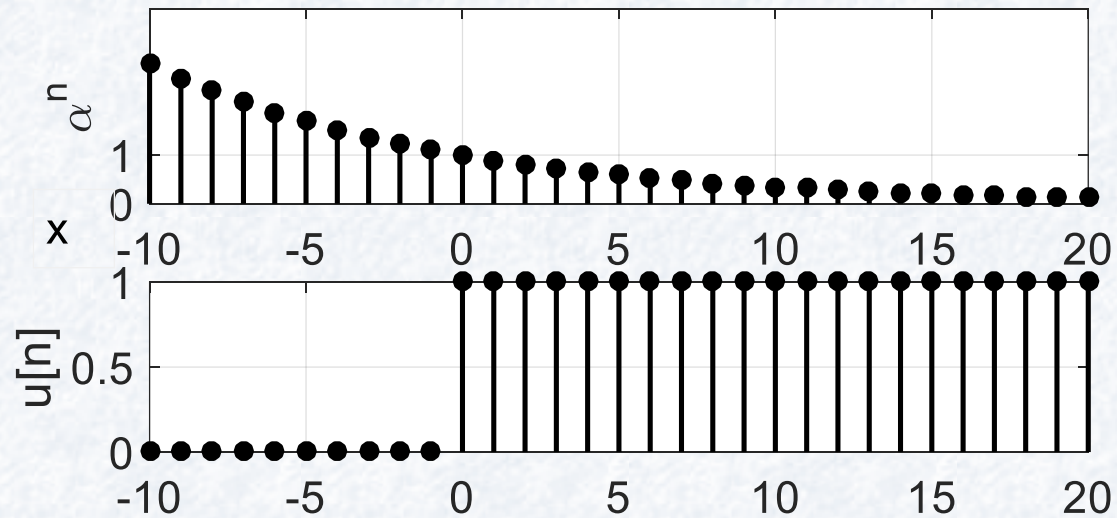
Dr. Seçkin Arı

Konvolüsyon

- Temel Sistem Özellikleri
- Doğrusal Zamanla Değişmez Sistemler
- Birim Darbe Cevabı

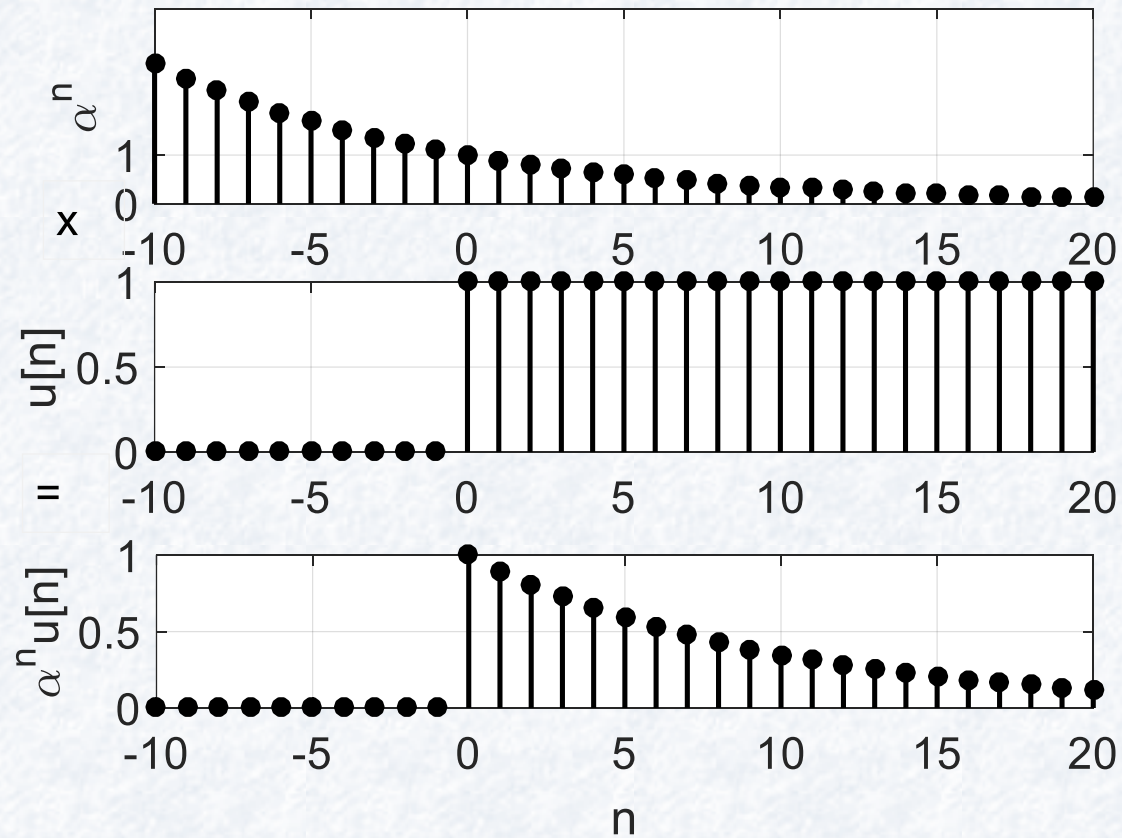
Örnek 1

- $x[n] = \alpha^n u[n]$



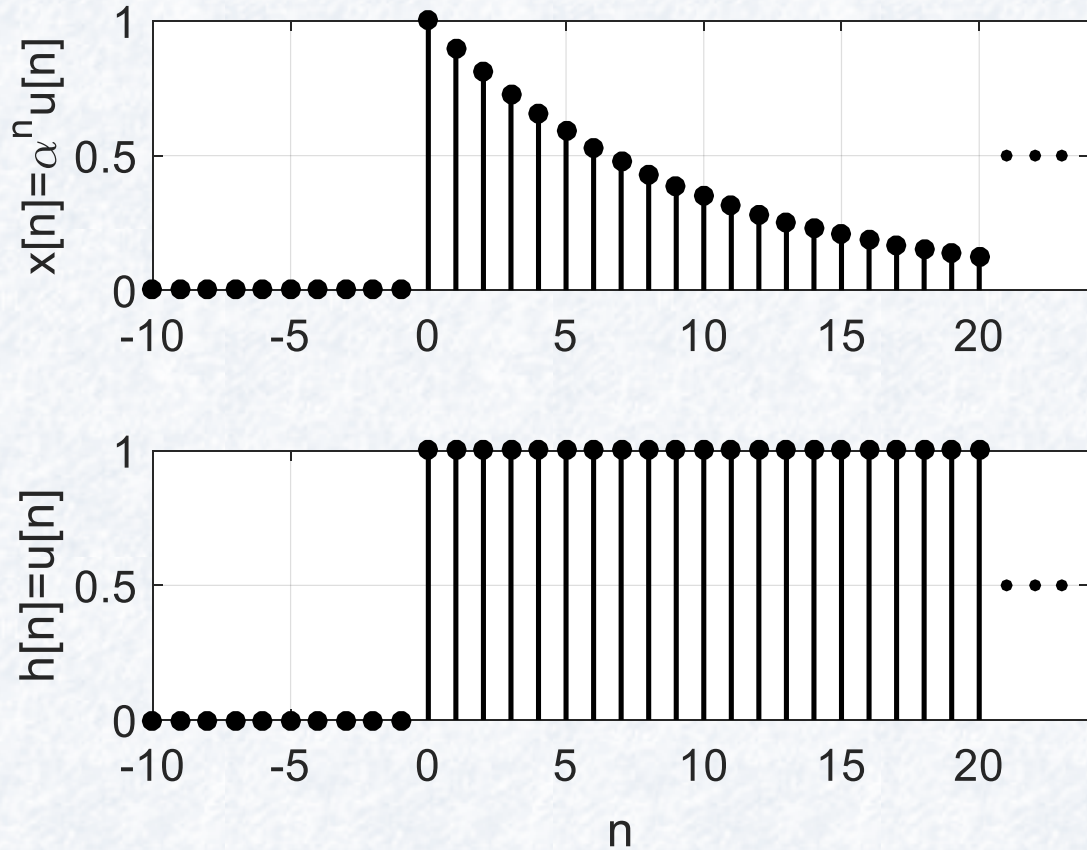
Örnek 1

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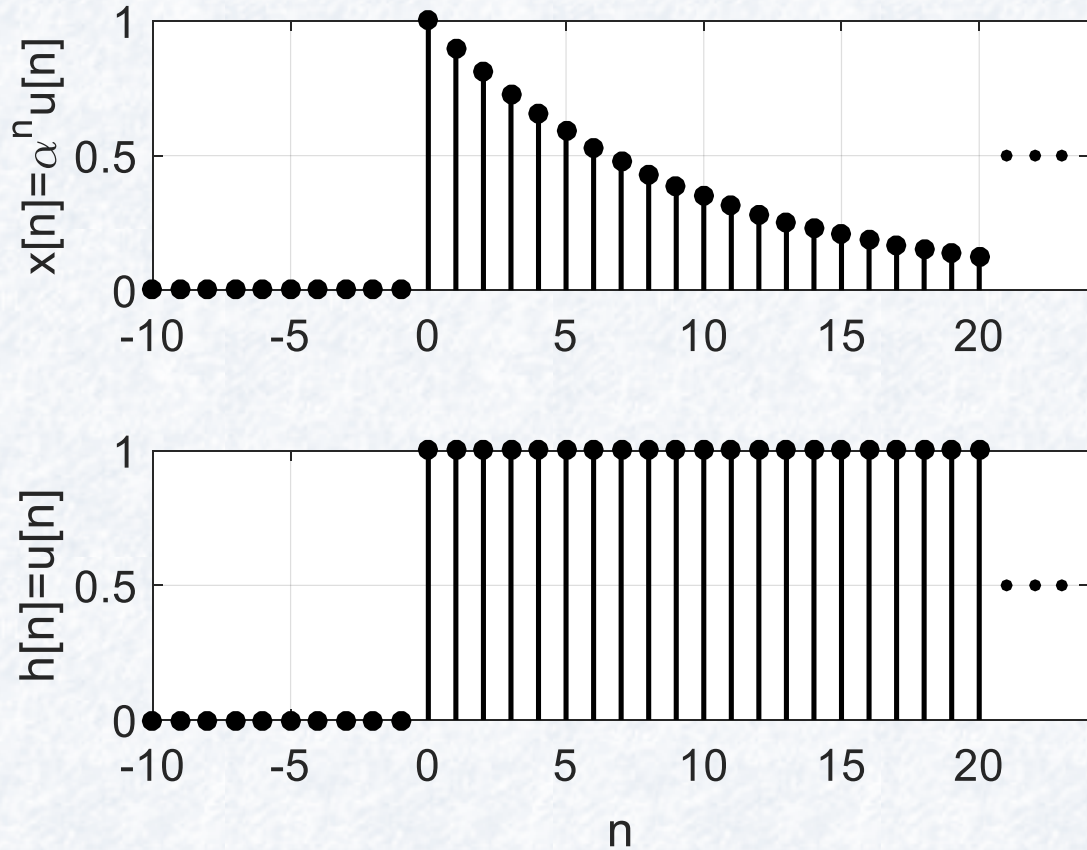
Örnek 1

- $x[n] = \alpha^n u[n]$
- $h[n] = u[n]$
- $y[n] = ?$



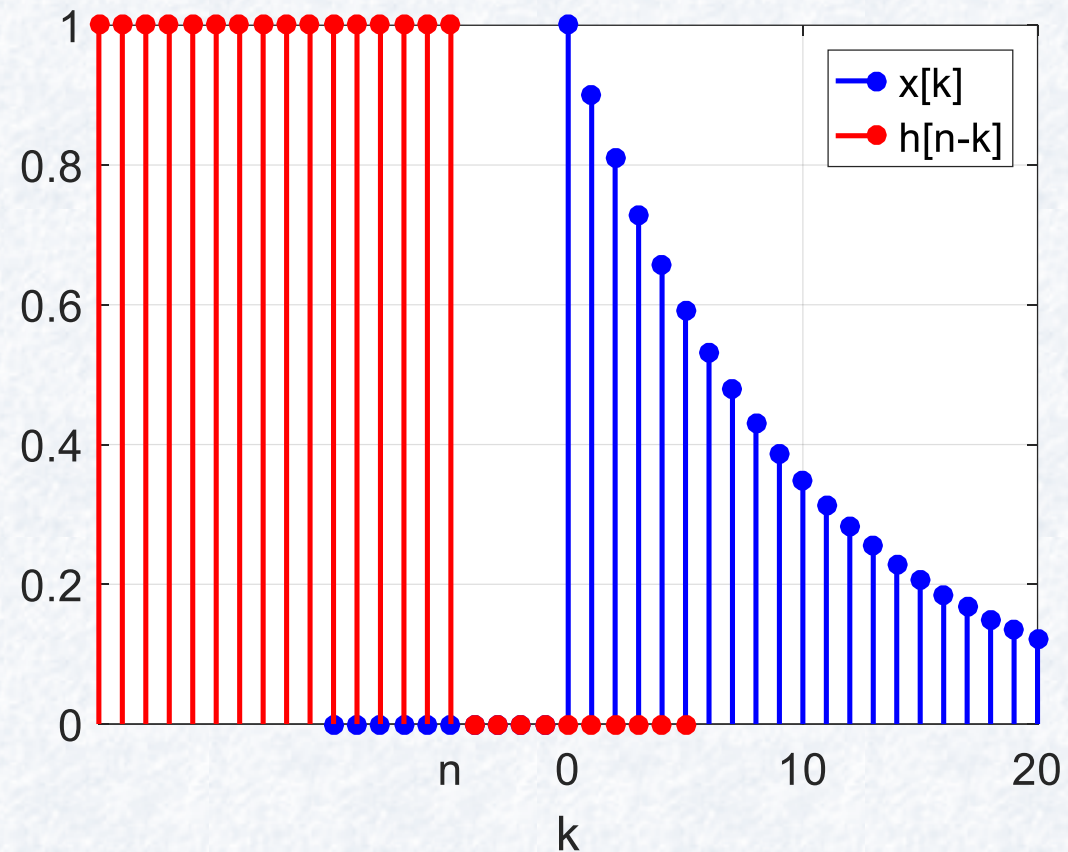
Örnek 1

- $x[n] = \alpha^n u[n]$
- $h[n] = u[n]$
- $y[n] = x[n] * h[n]$



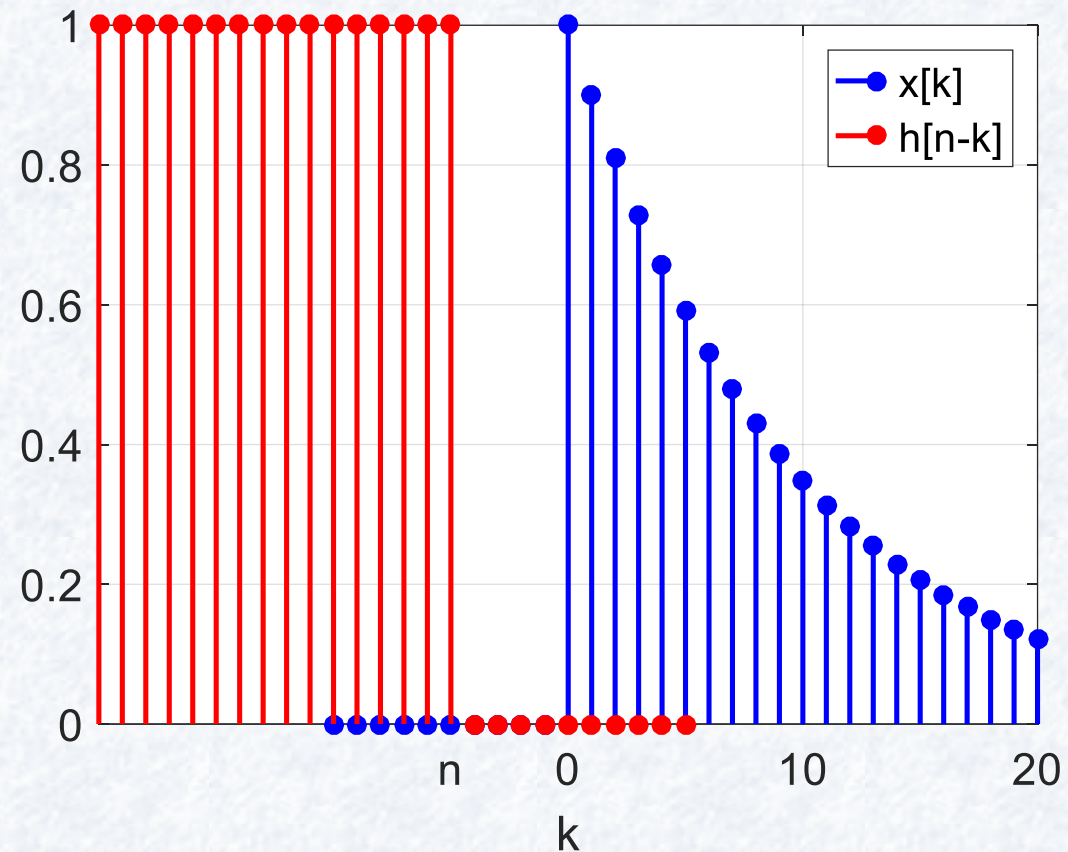
Örnek 1

- $x[n] = \alpha^n u[n]$
- $h[n] = u[n]$
- $y[n] = x[n] * h[n]$
- $n < 0$ iken



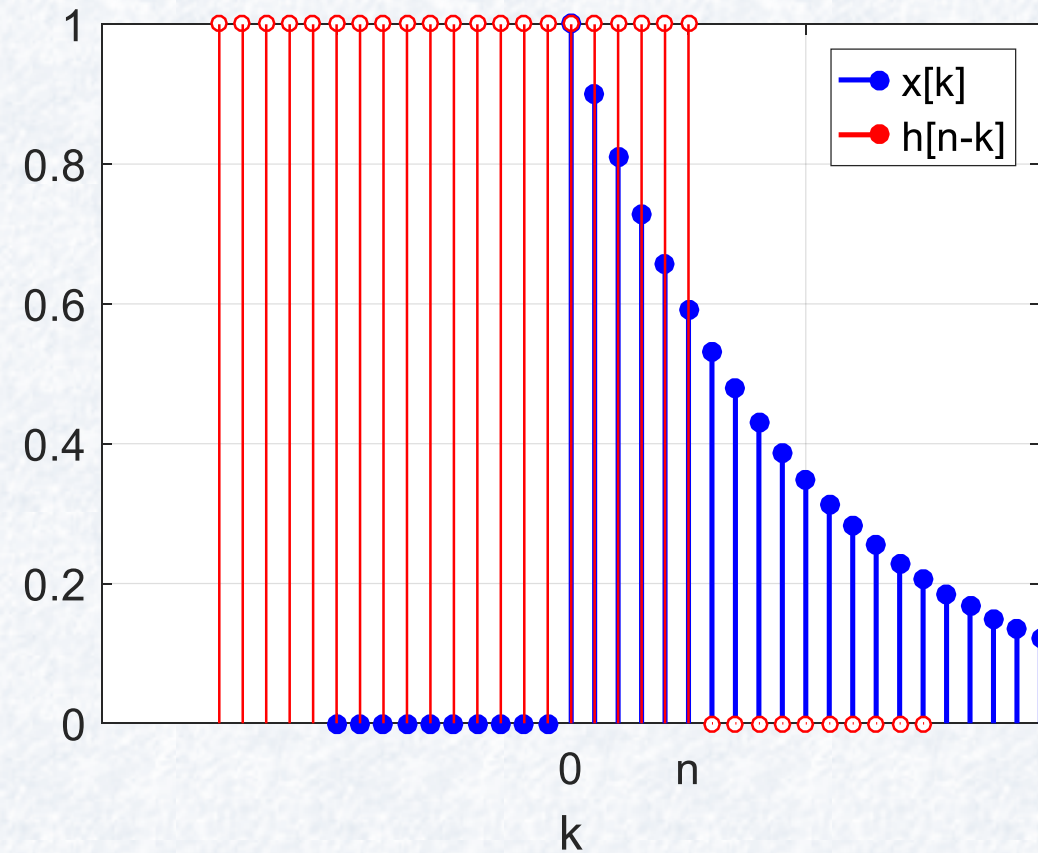
Örnek 1

- $x[n] = \alpha^n u[n]$
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- $n < 0$ iken
 - ♦ Çakışma yok
- $y[n] = 0$



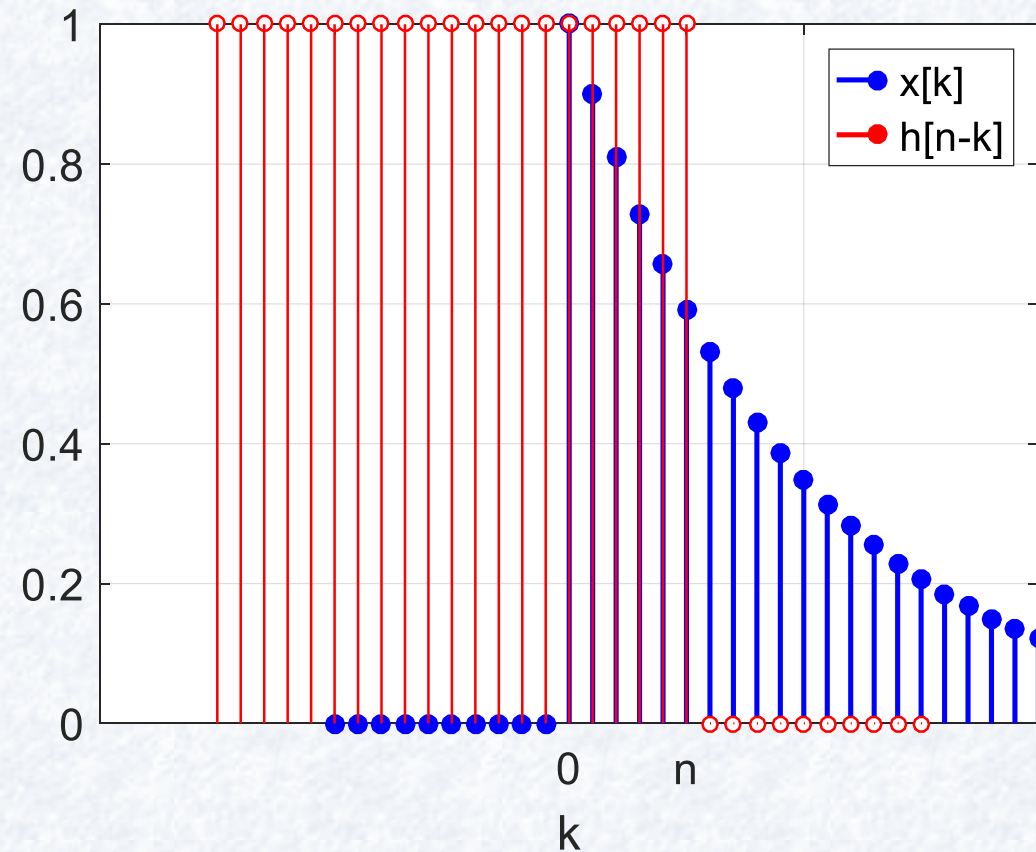
Örnek 1

- $x[n] = \alpha^n u[n]$
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- $n \geq 0$ iken



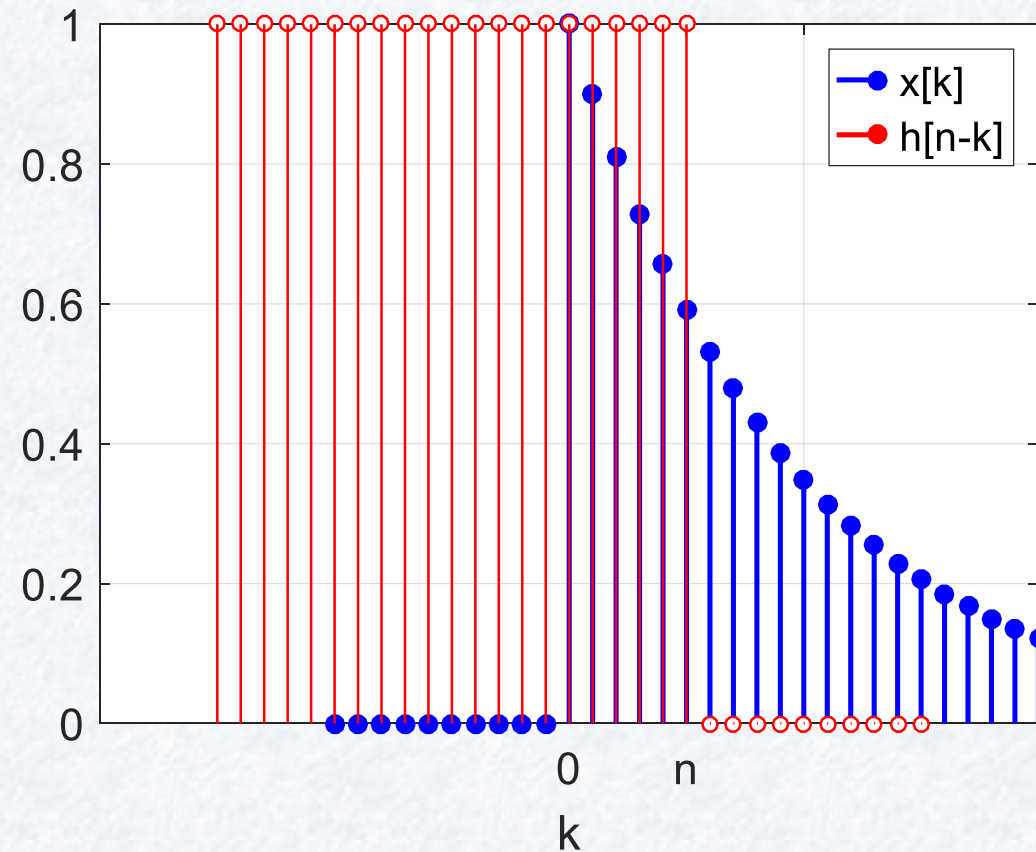
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 - ♦ Çakışma 0-n arası
- $y[n] = \sum_{k=0}^n \alpha^k \cdot 1$
- $y[n] =$



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- $x[n] = \alpha^n u[n]$
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- $y[n] = \frac{1 - \alpha^{n+1}}{1 - \alpha}$



Örnek 1

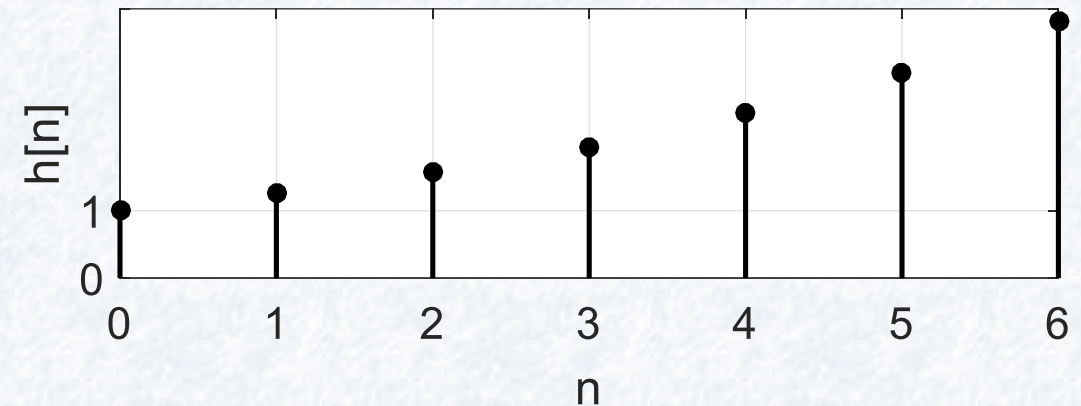
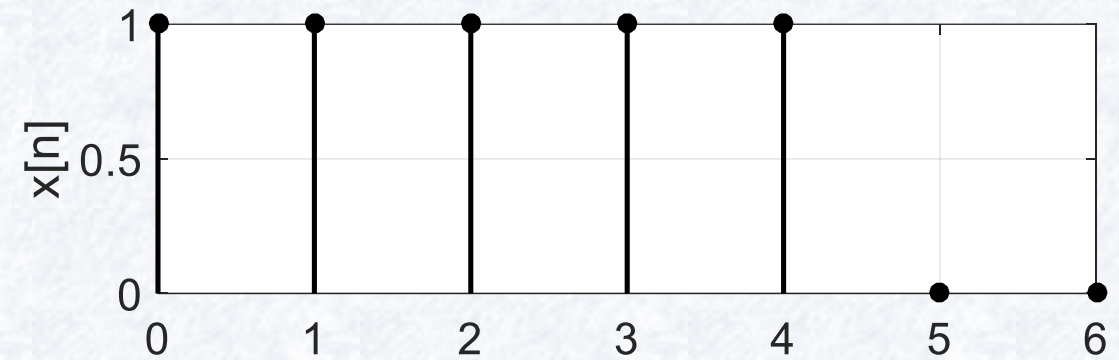
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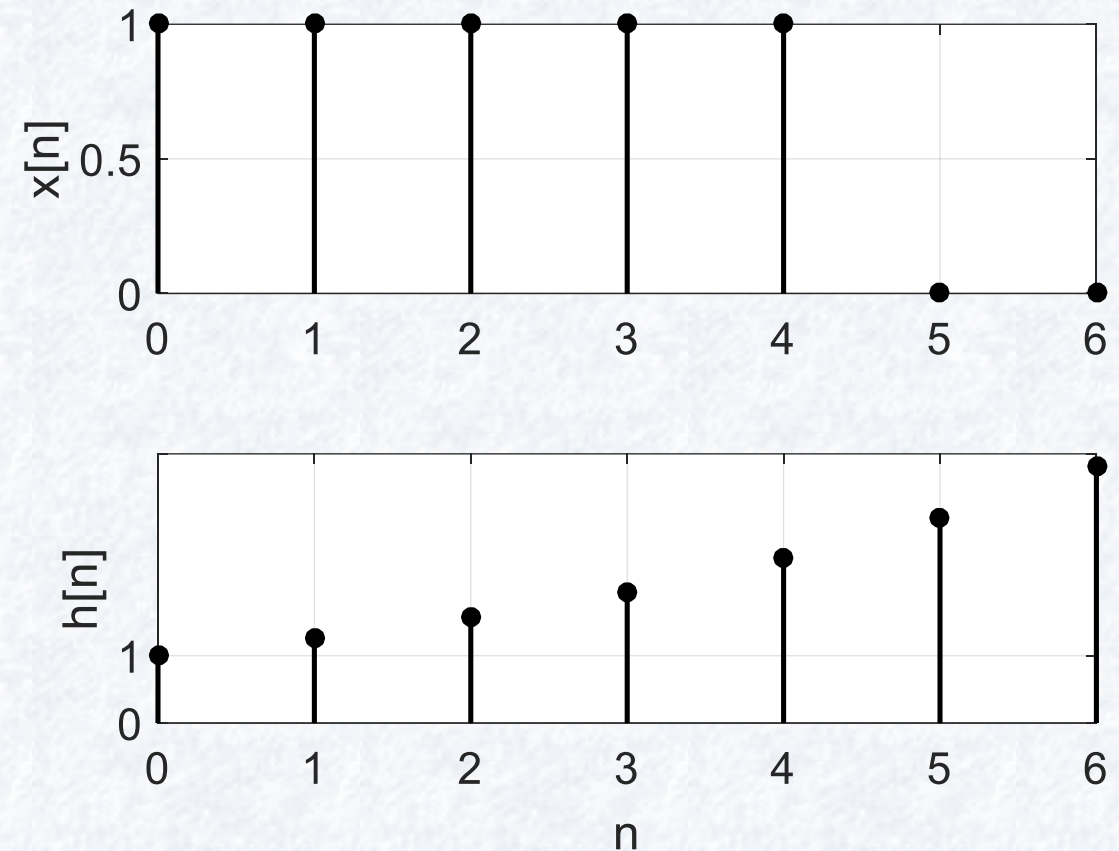
Örnek 2

- $x[n] = \begin{cases} 1, & 0 \leq n \leq 4 \\ 0, & \text{diğer} \end{cases}$
- $h[n] = \begin{cases} \alpha^n, & 0 \leq n \leq 6 \\ 0, & \text{diğer} \end{cases}$
- $y[n] = ?$



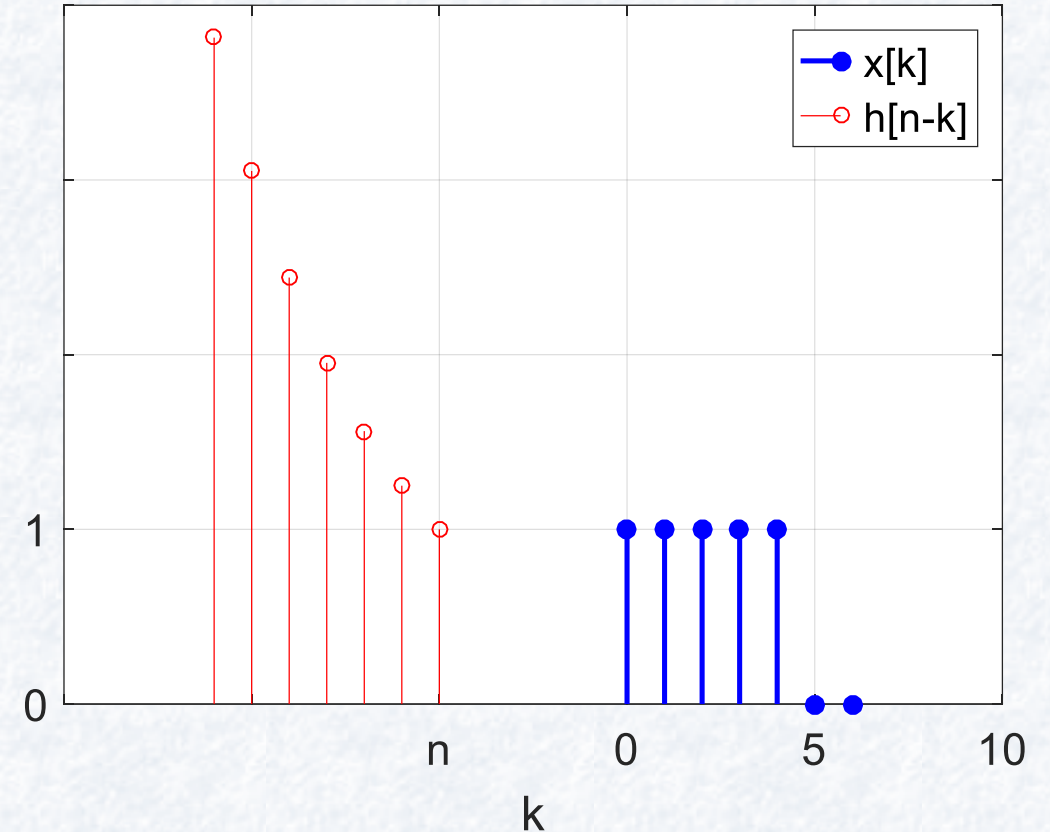
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- $n < 0$ iken



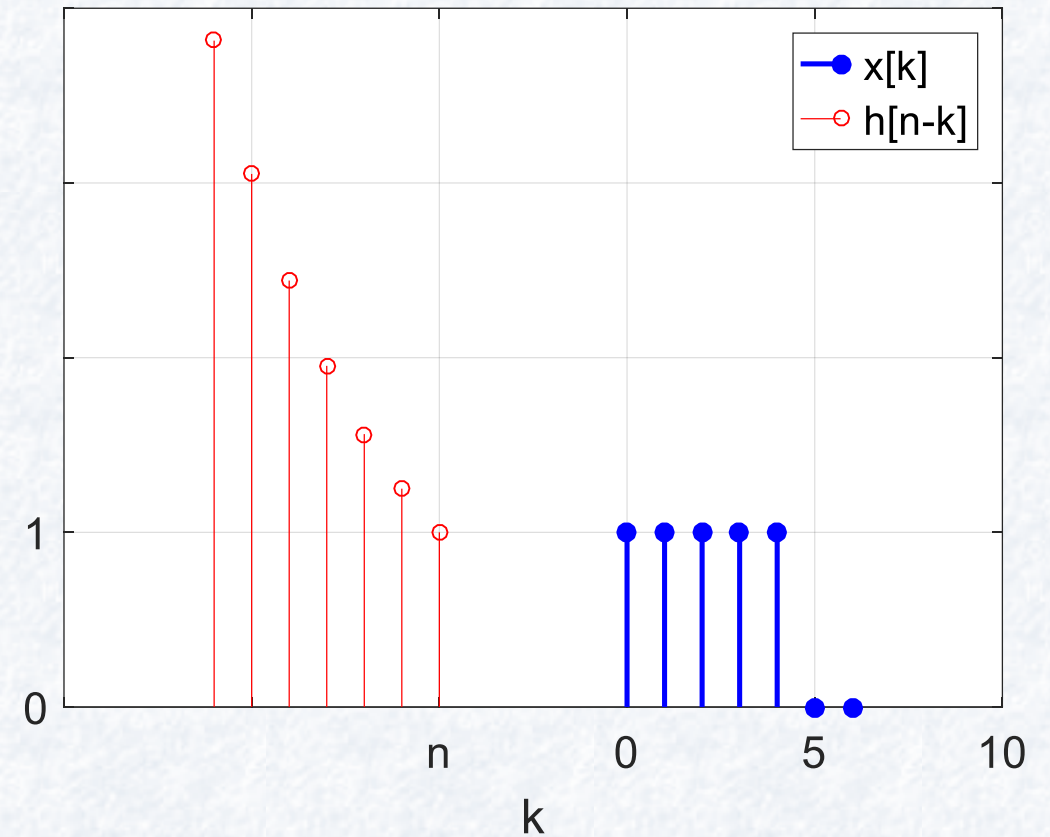
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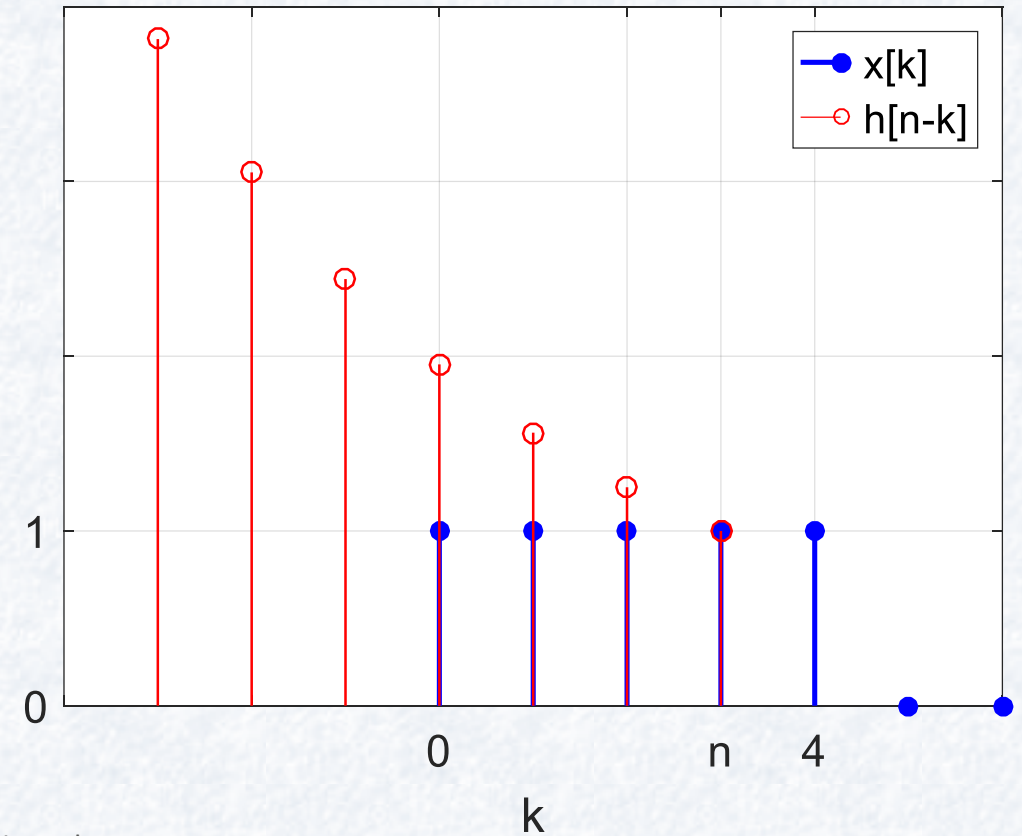
Örnek 2

- $0 \leq n \leq 4$ iken



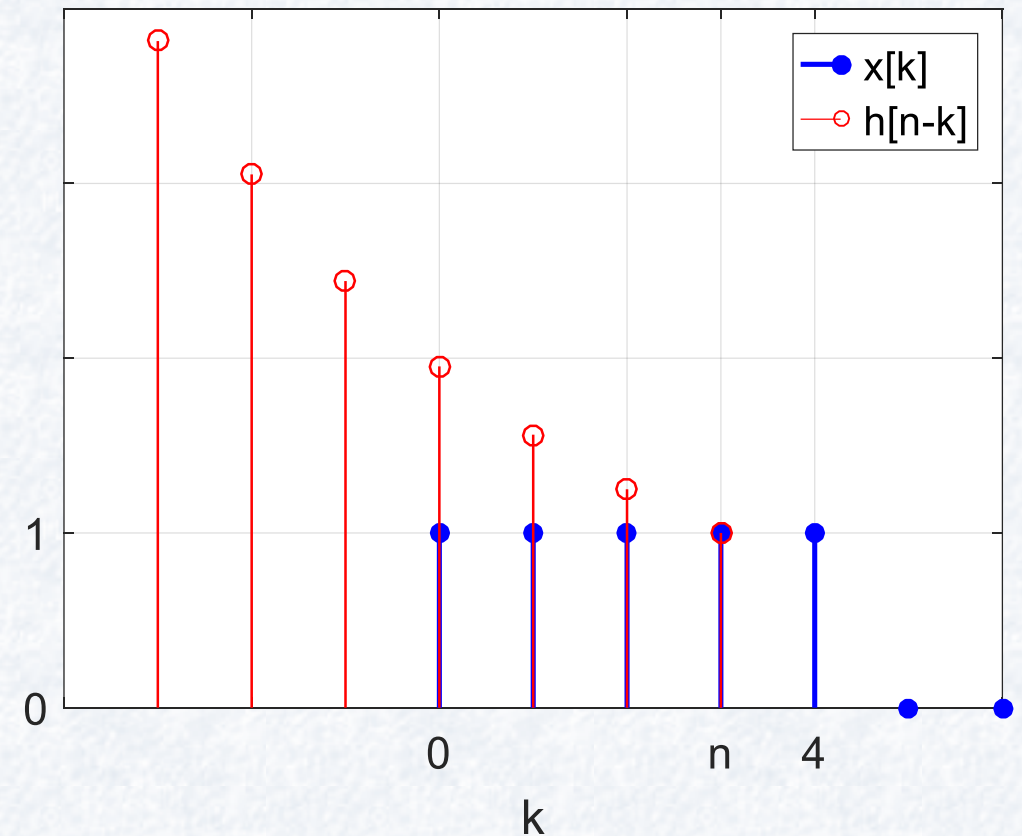
Örnek 2

- $0 \leq n \leq 4$ iken
 - ♦ Çakışma,



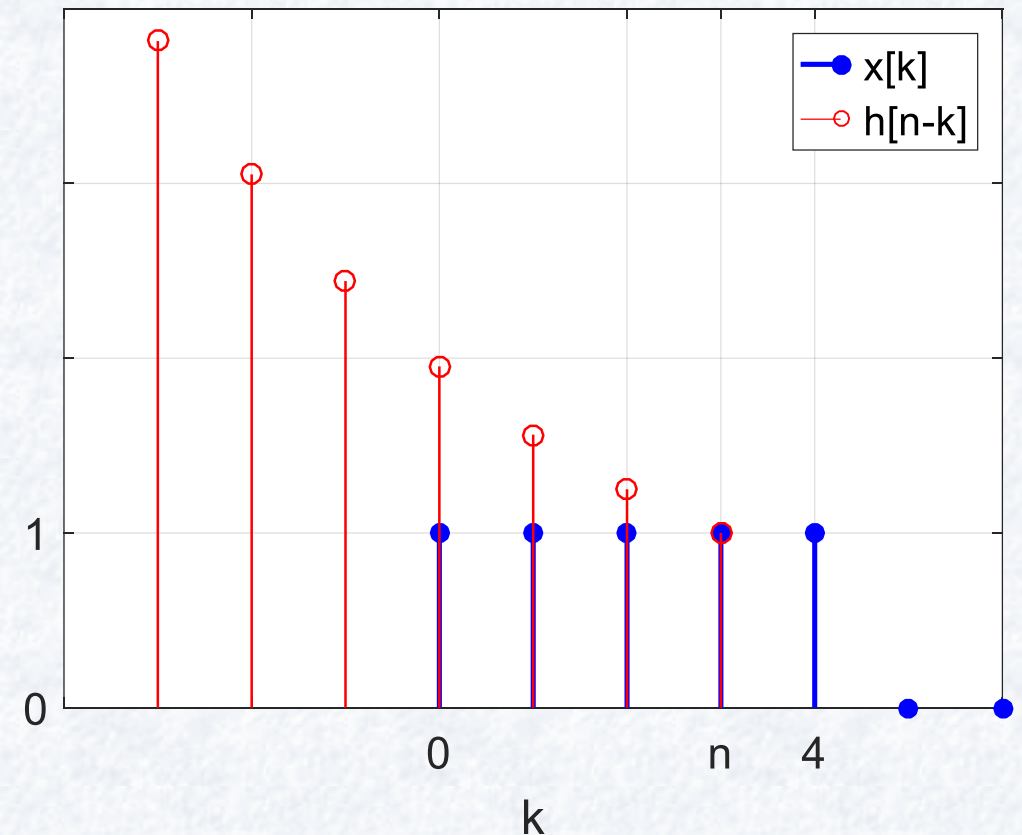
Örnek 2

- $0 \leq n \leq 4$ iken
 - ♦ Çakışma, 0-n arası
- $y[n] = \sum_{k=0}^n x[k]h[n-k]$
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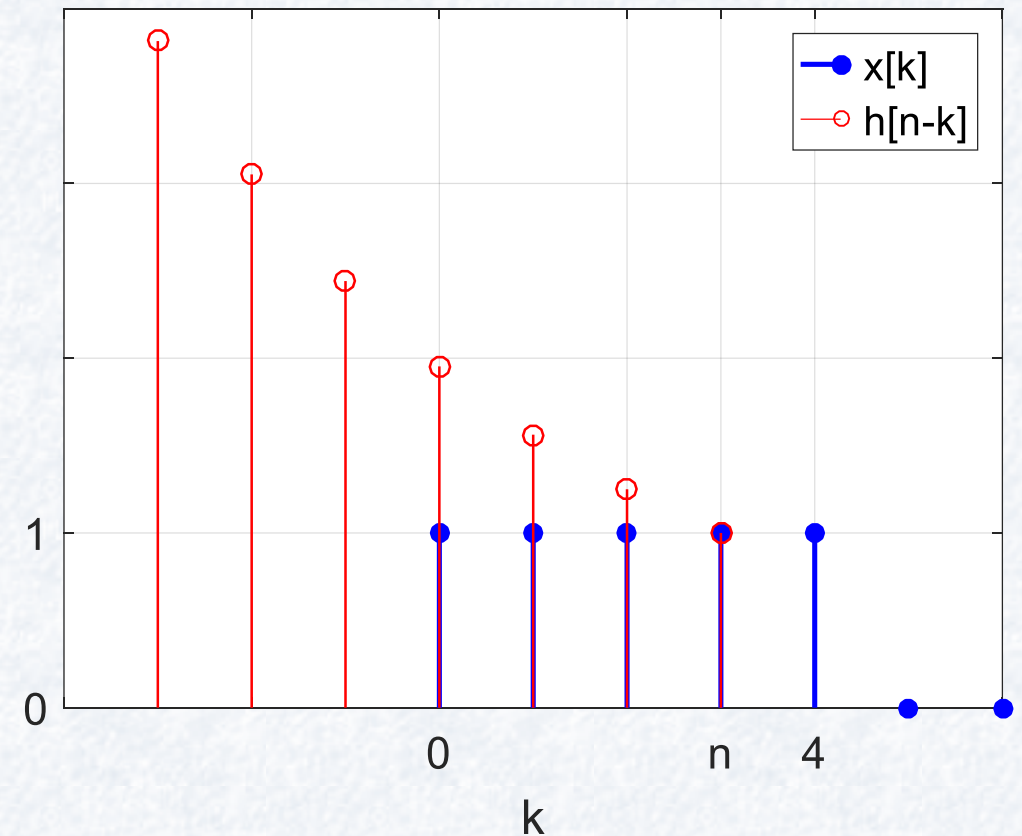
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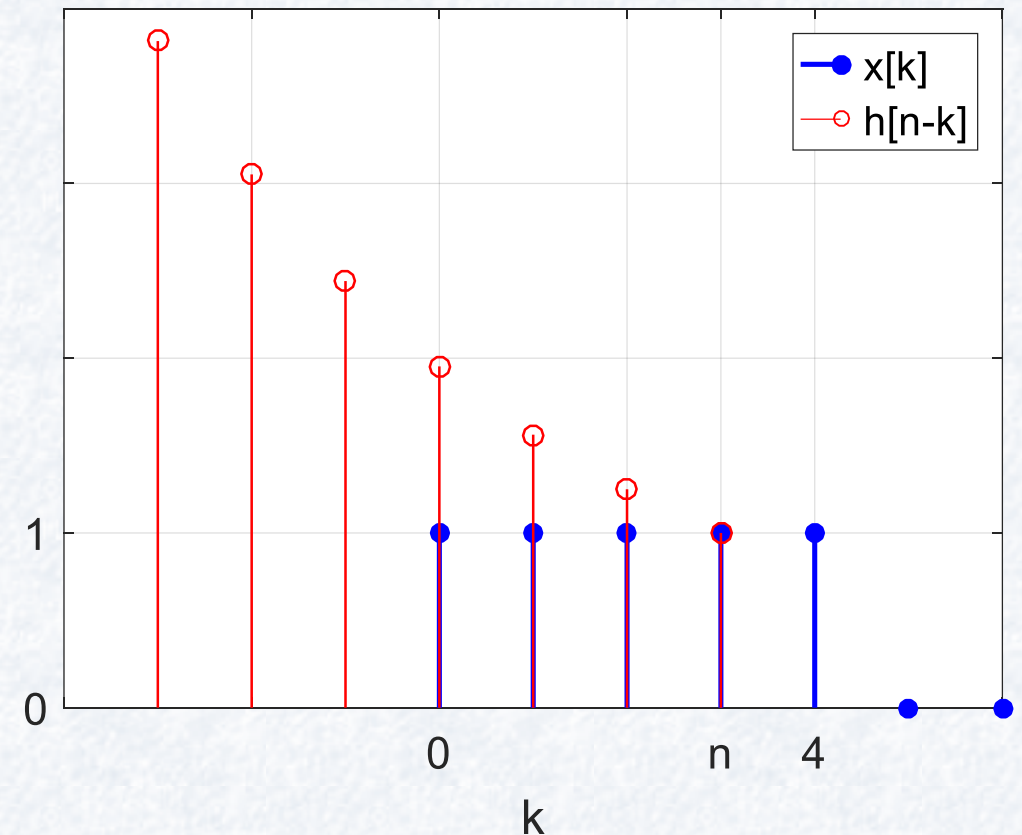
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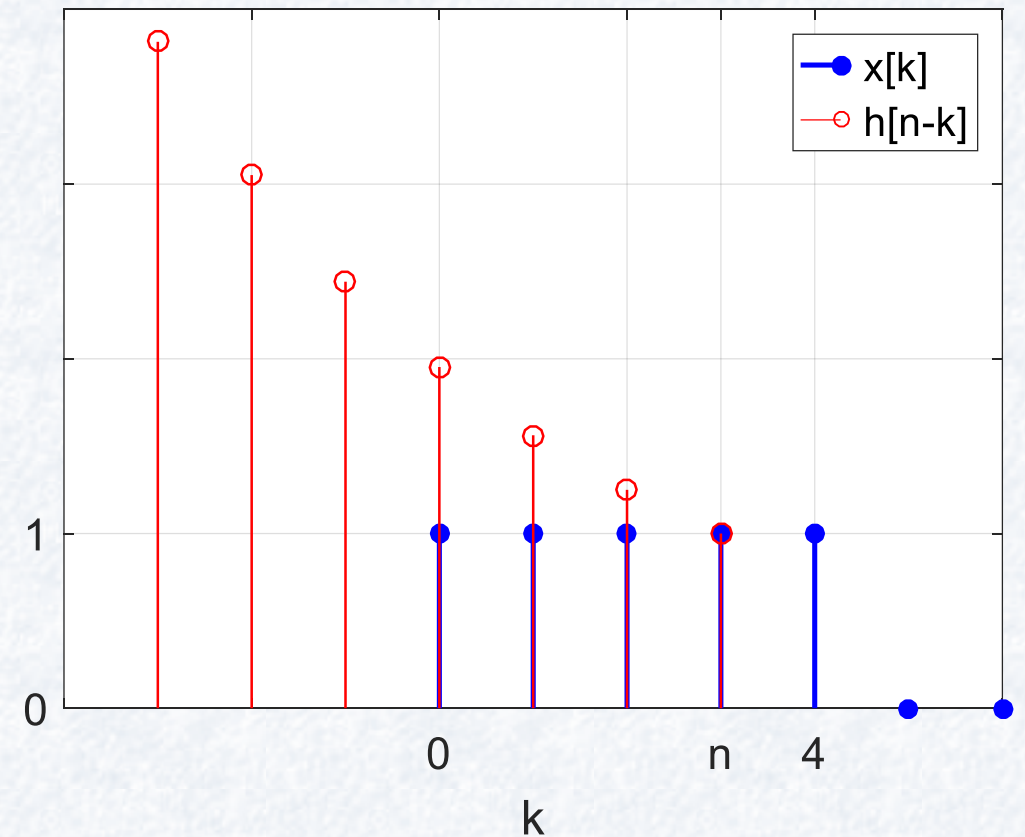
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- $y[n] = \alpha^n \sum_{k=0}^n \left(\frac{1}{\alpha}\right)^k$



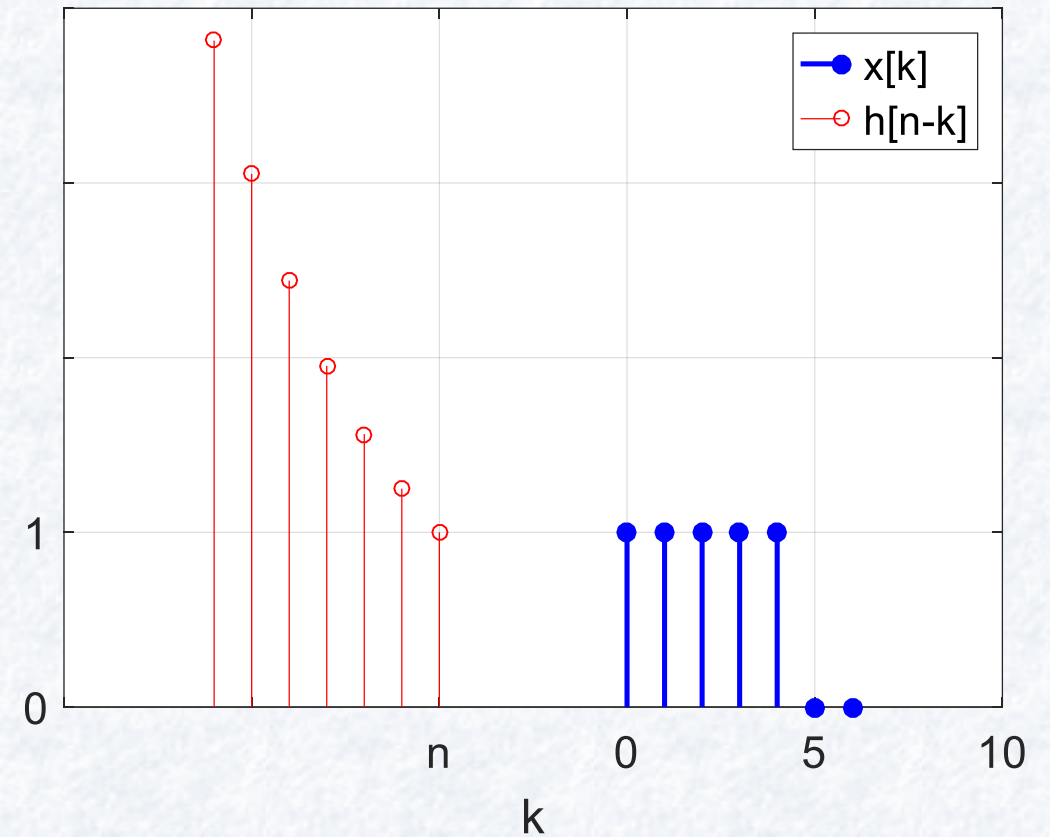
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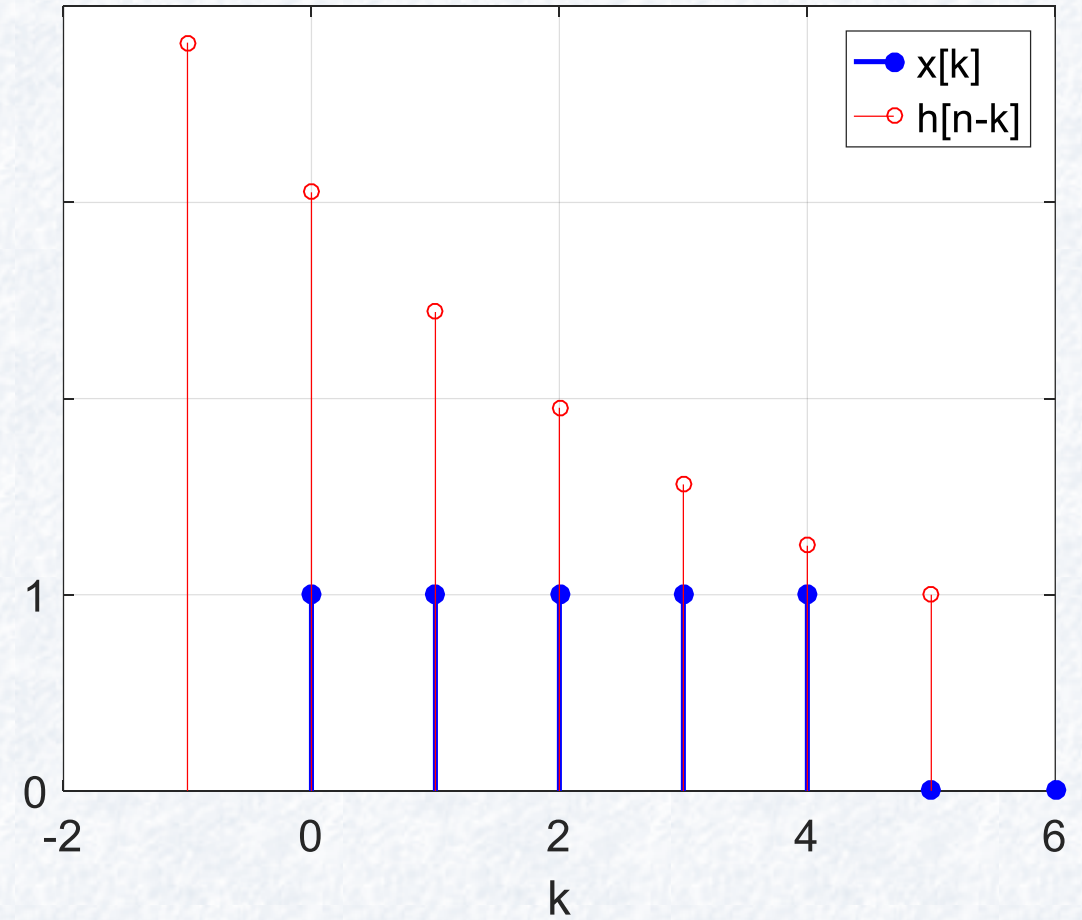
Örnek 2

- $4 < n \leq 6$ iken



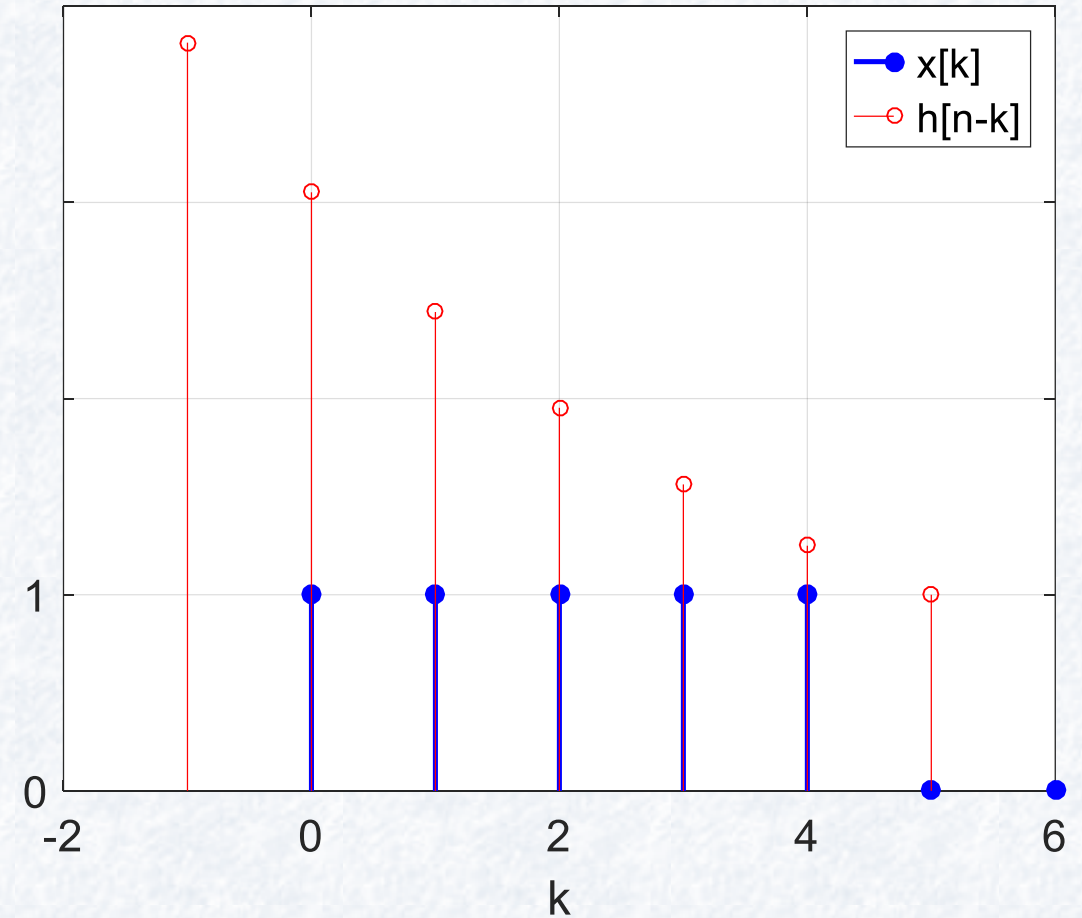
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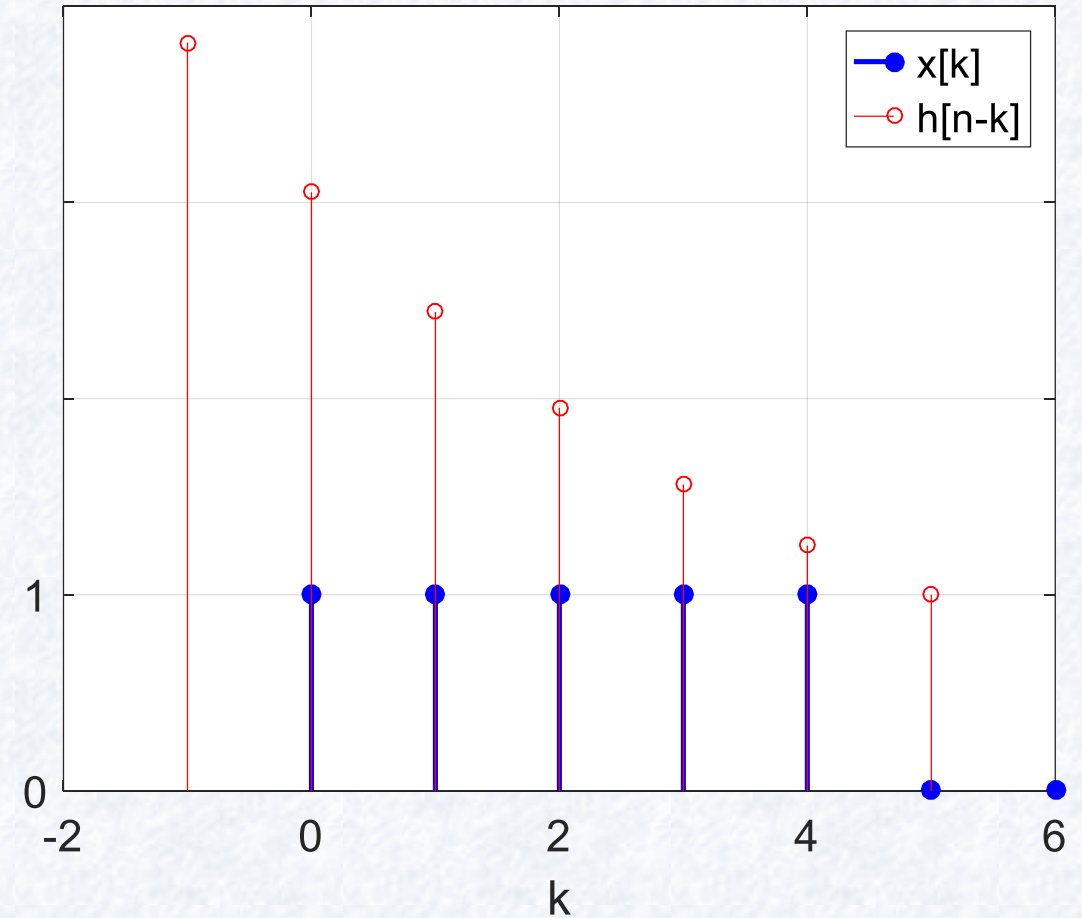
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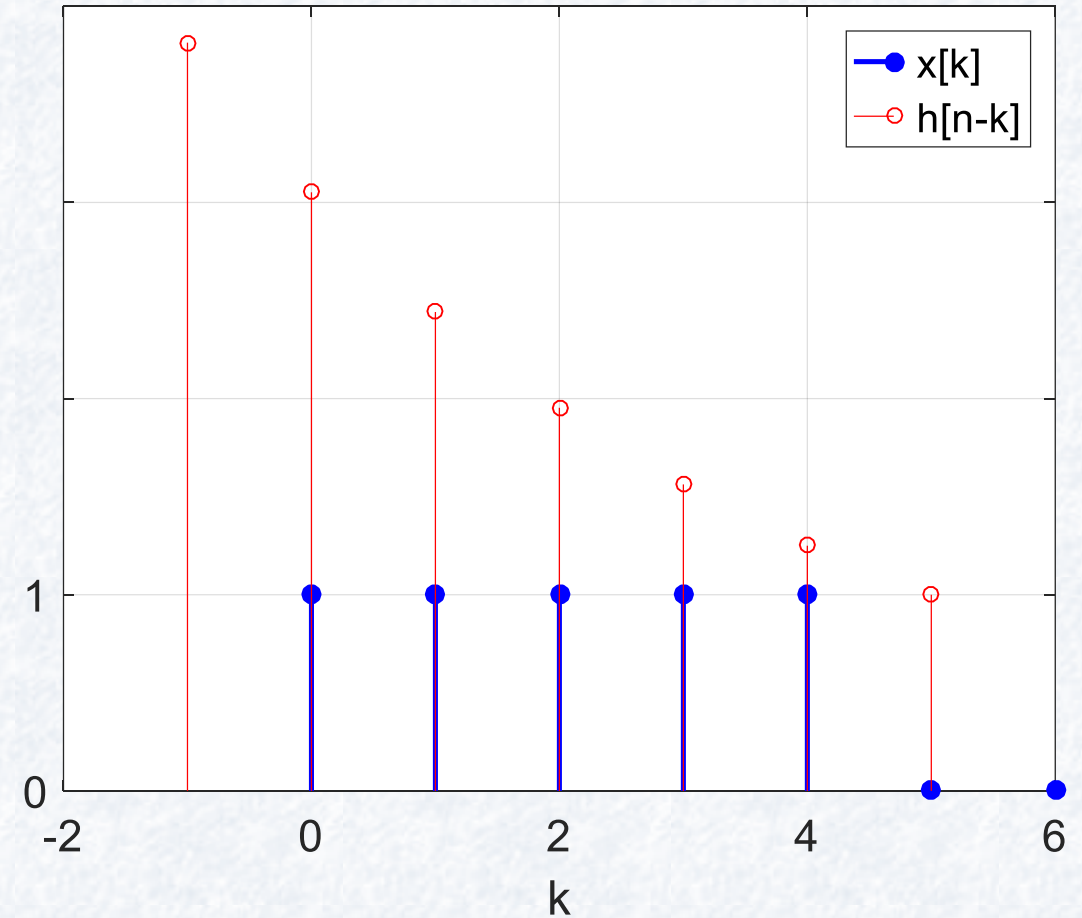
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- $4 < n \leq 6$ iken
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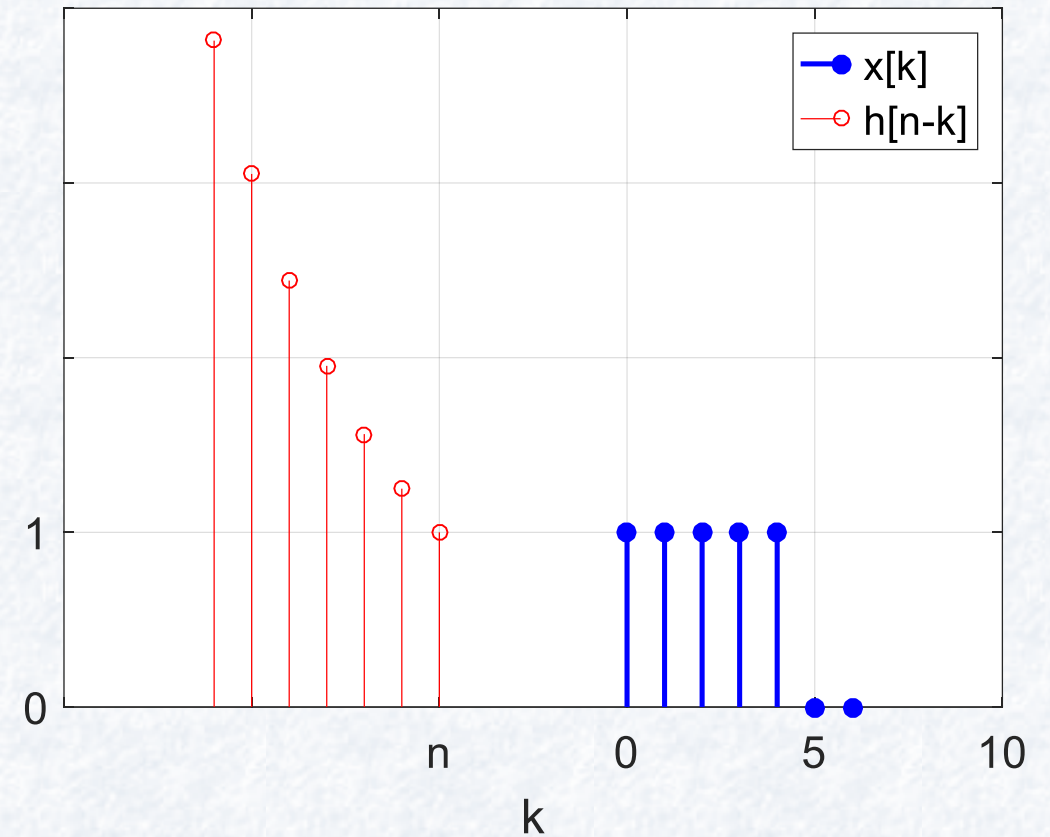
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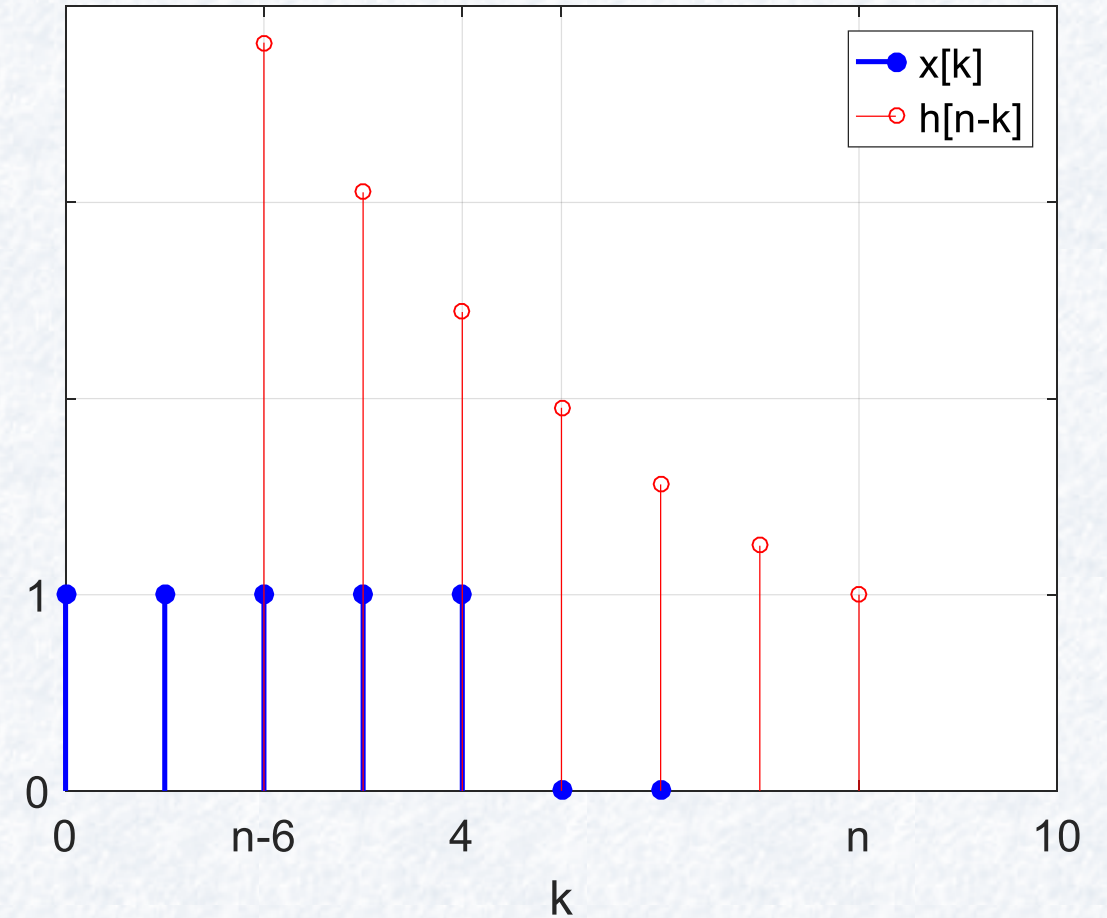
Örnek 2

- $6 < n \leq 10$ iken



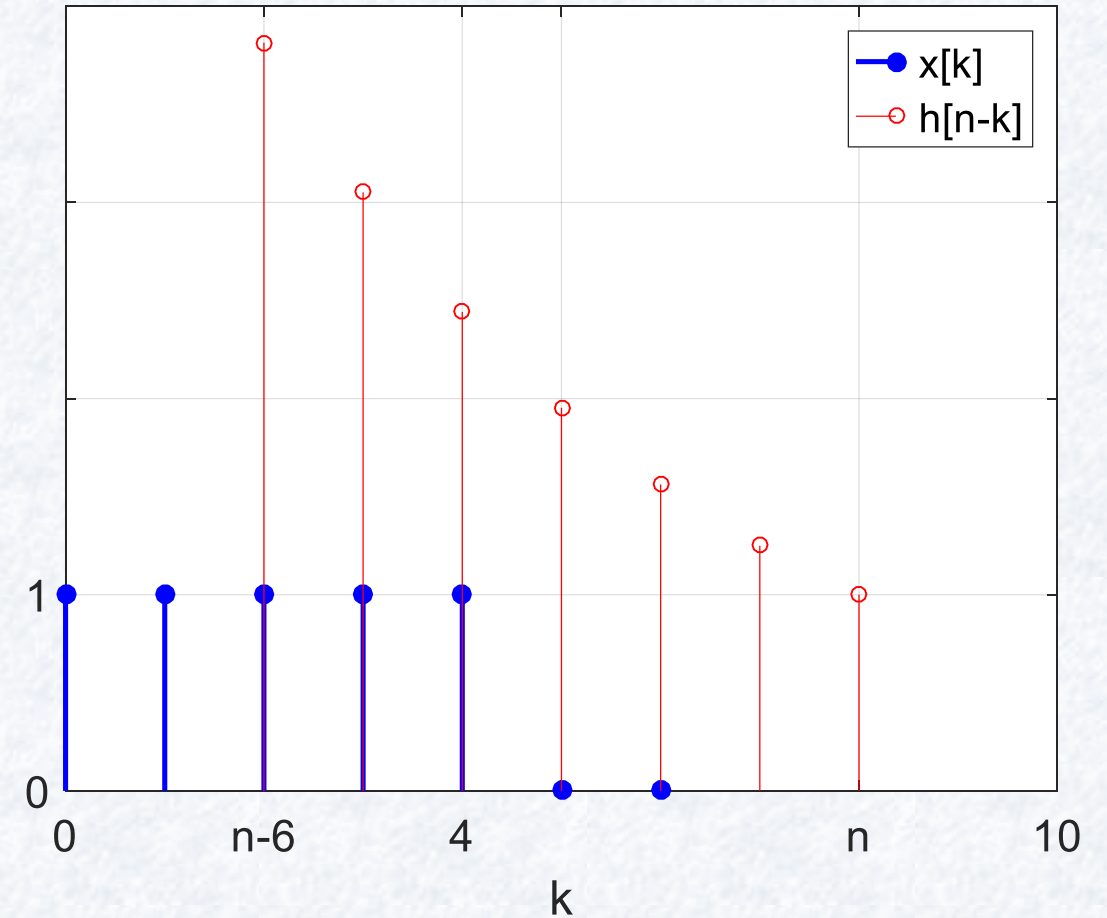
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- $6 < n \leq 10$ iken
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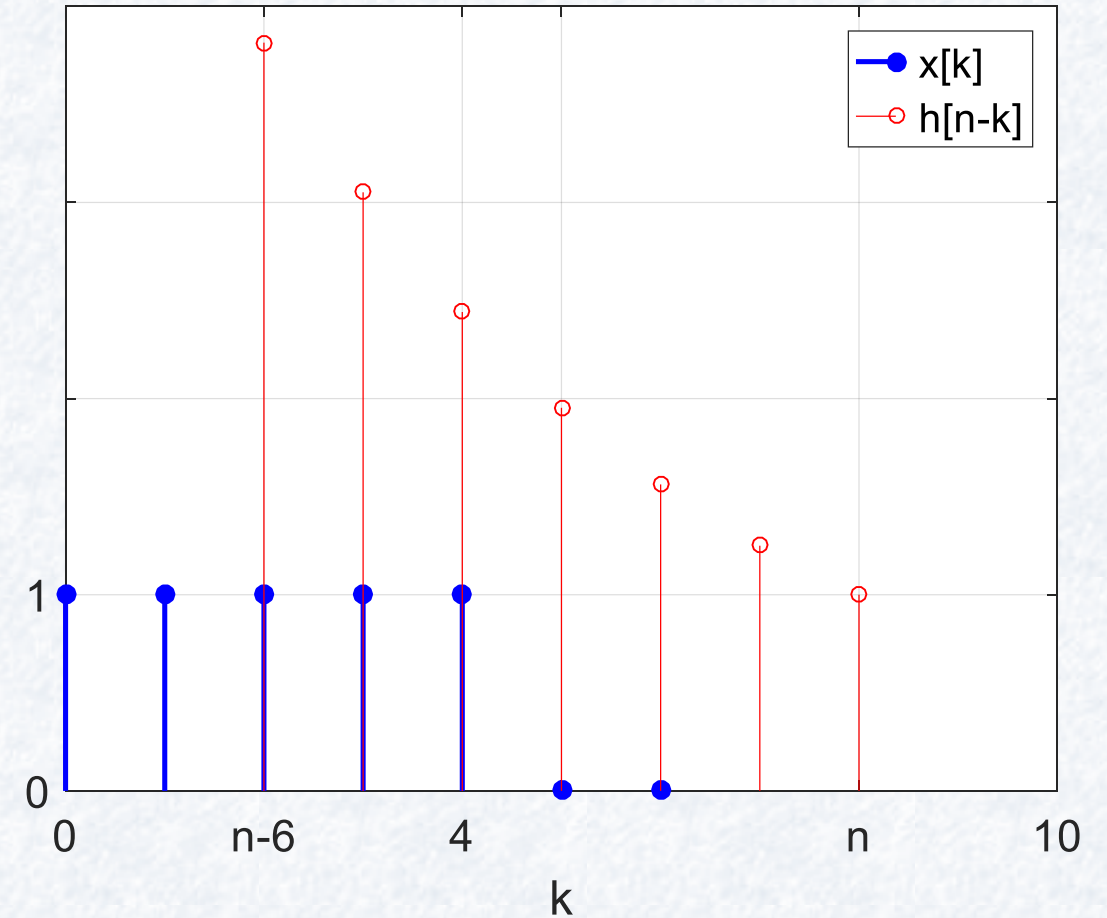
Örnek 2

- $6 < n \leq 10$ iken
 - ♦ Çakışma, $n-6 - 4$ arası



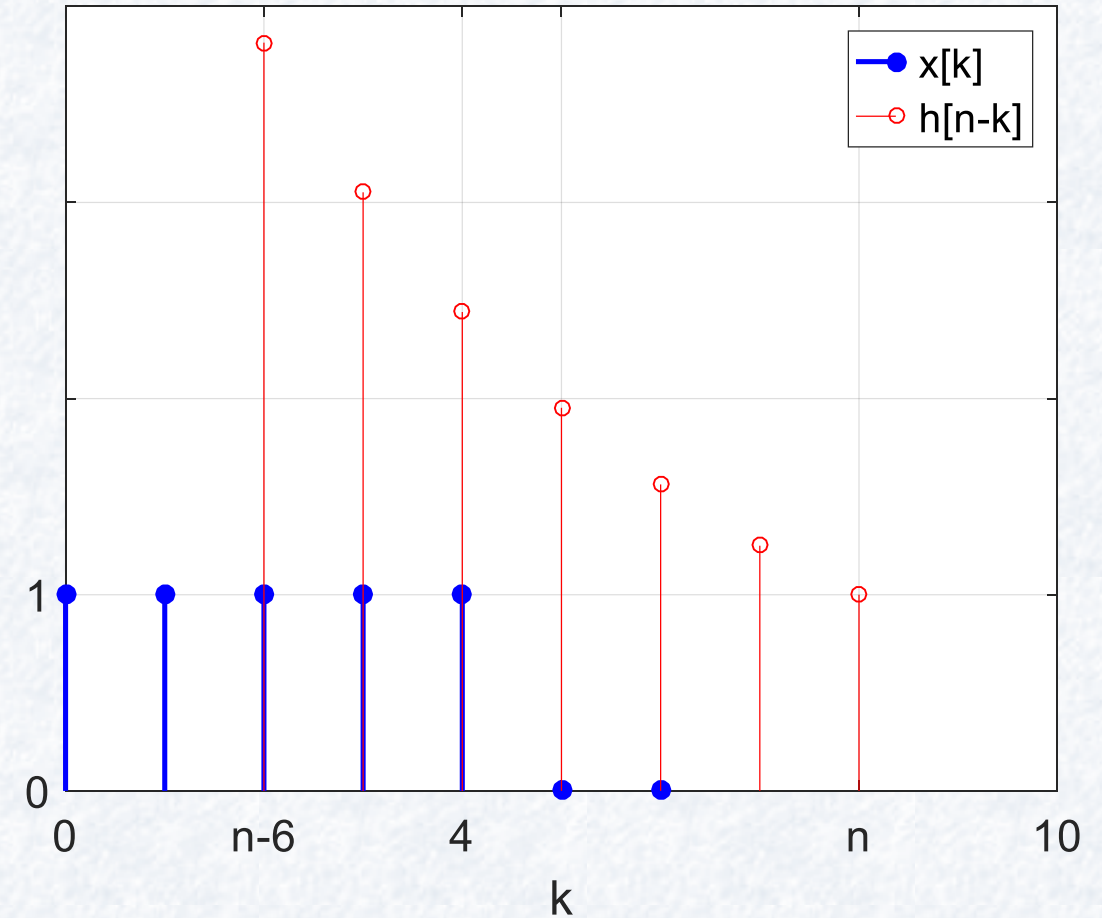
Örnek 2

- $6 < n \leq 10$ iken
 - ♦ Çakışma, $n-6 - 4$ arası
- $y[n] = \sum_{k=n-6}^4 x[k]h[n-k]$



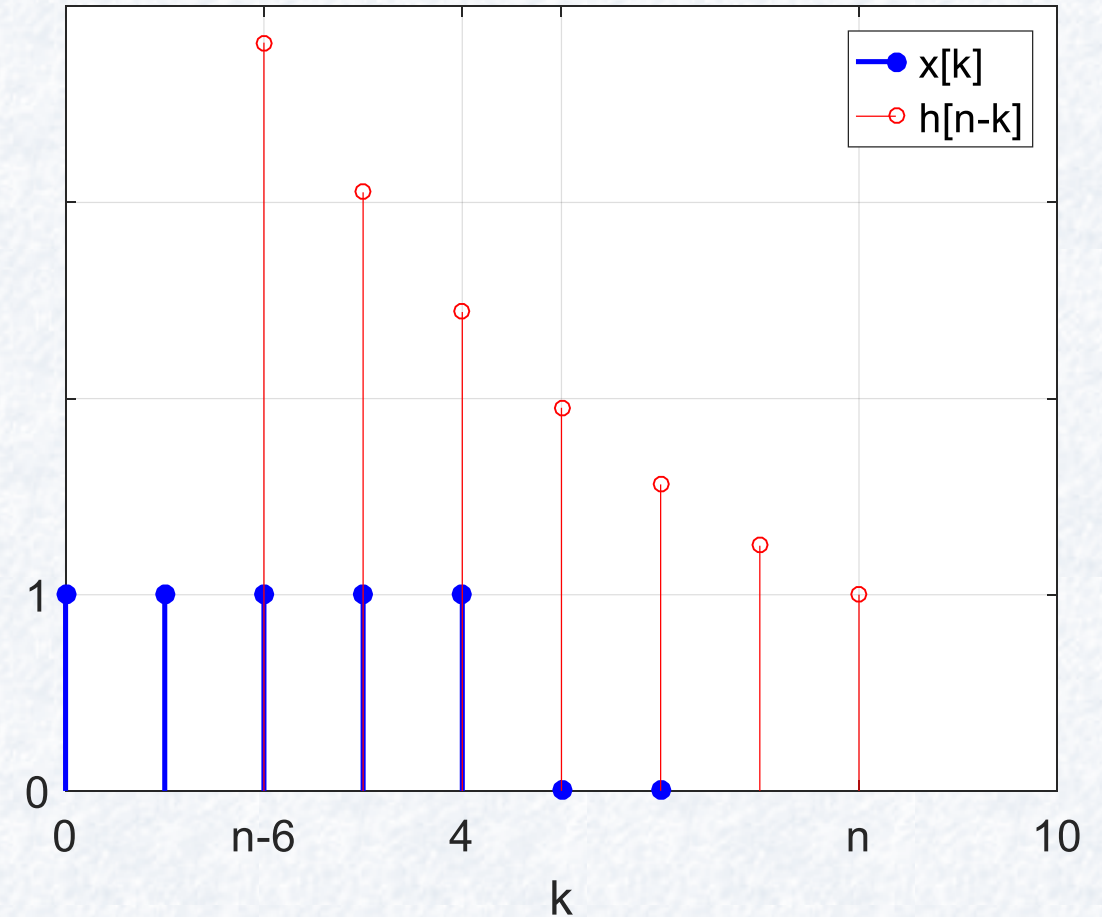
Örnek 2

- $6 < n \leq 10$ iken
 - ♦ Çakışma, $n-6 - 4$ arası
- $y[n] = \sum_{k=n-6}^4 x[k]h[n-k]$
- $y[n] = \alpha^n \sum_{k=n-6}^4 \alpha^{-k}$
 - ♦ $l = k - n + 6$



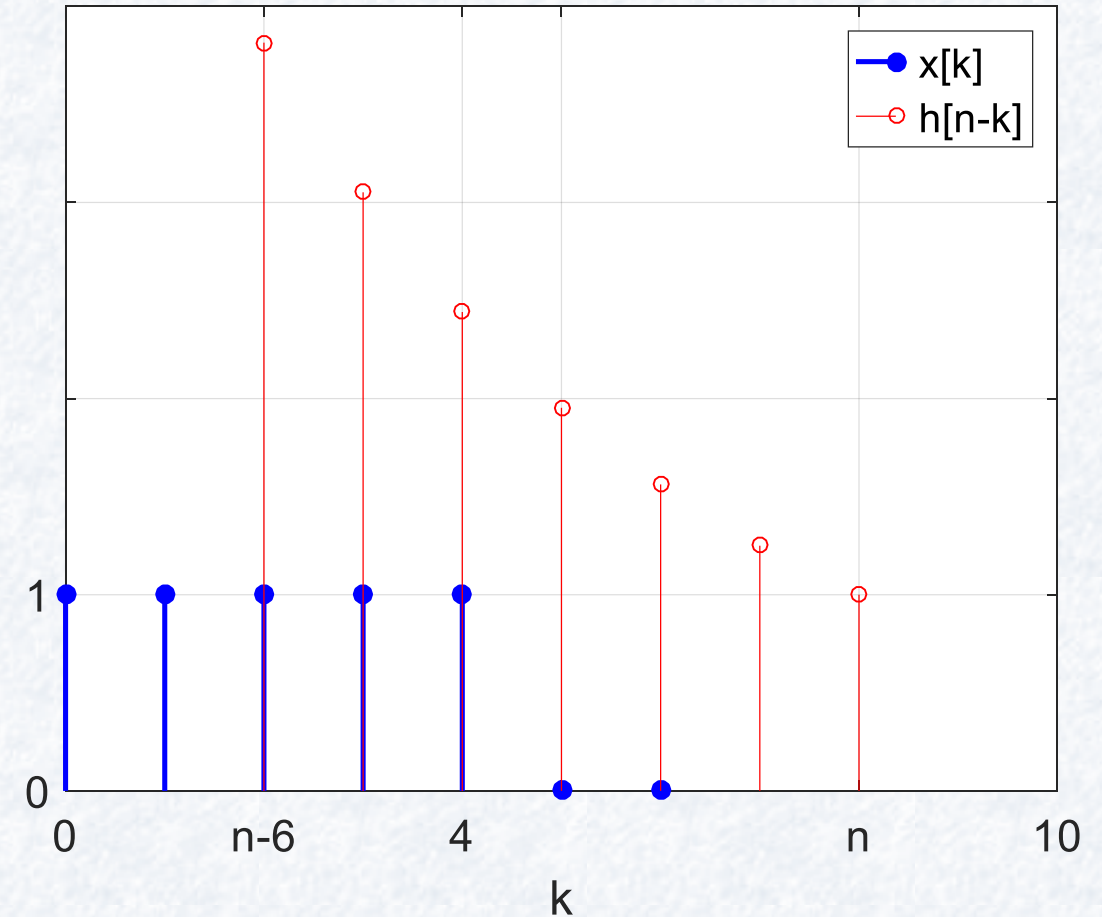
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 - ♦ $l = k - n + 6$
- $y[n] = \alpha^n \sum_{l=0}^{10-n} \alpha^{-l-n+6}$



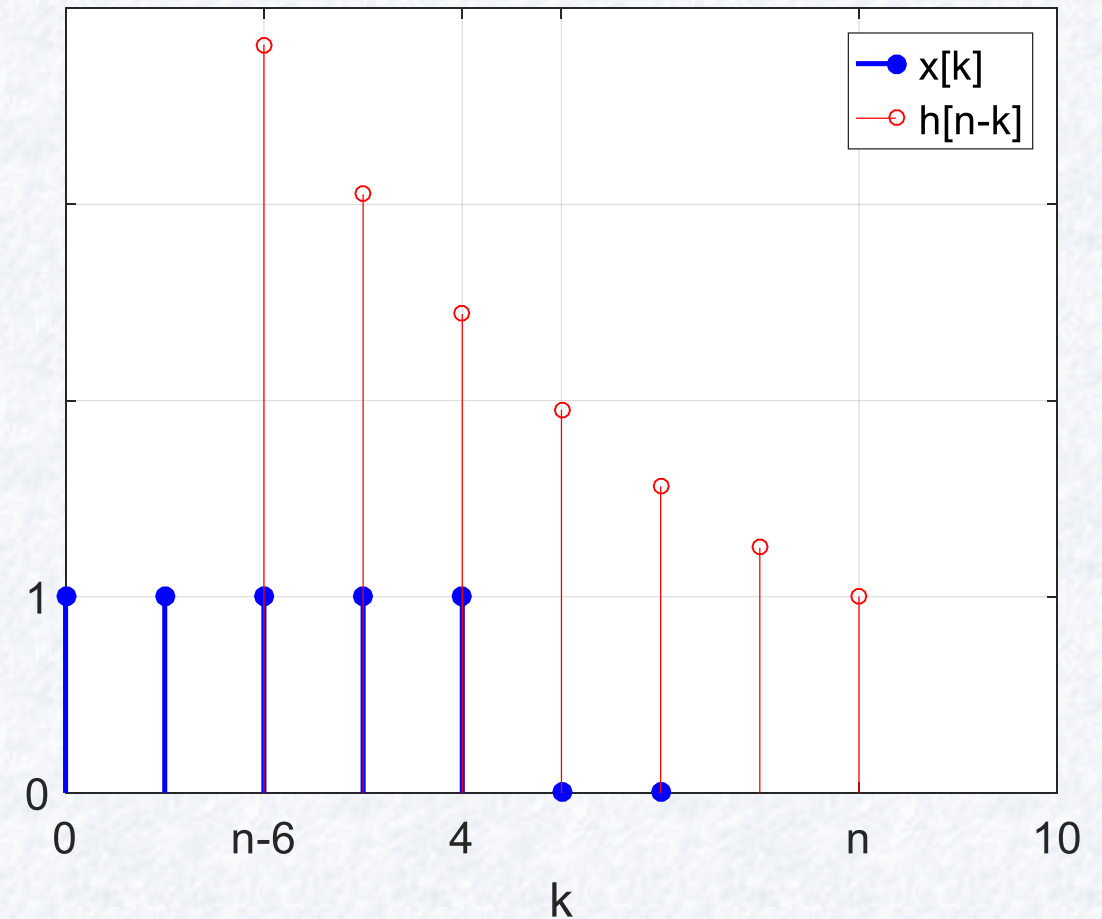
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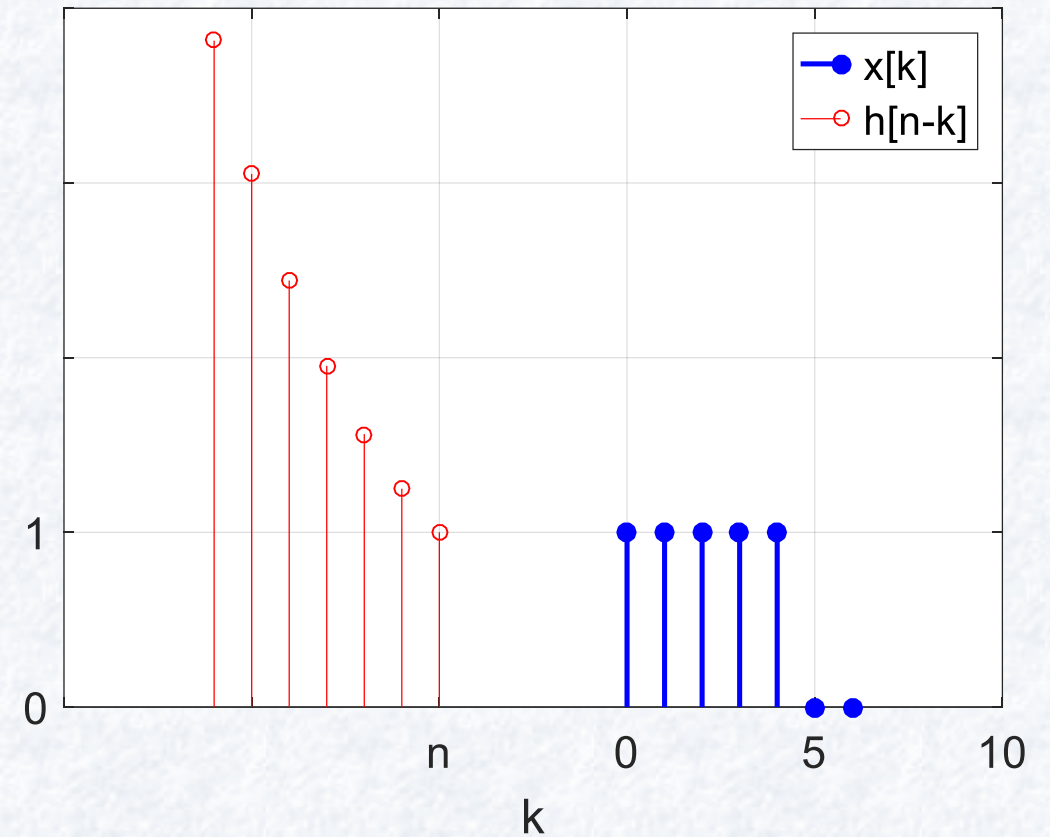
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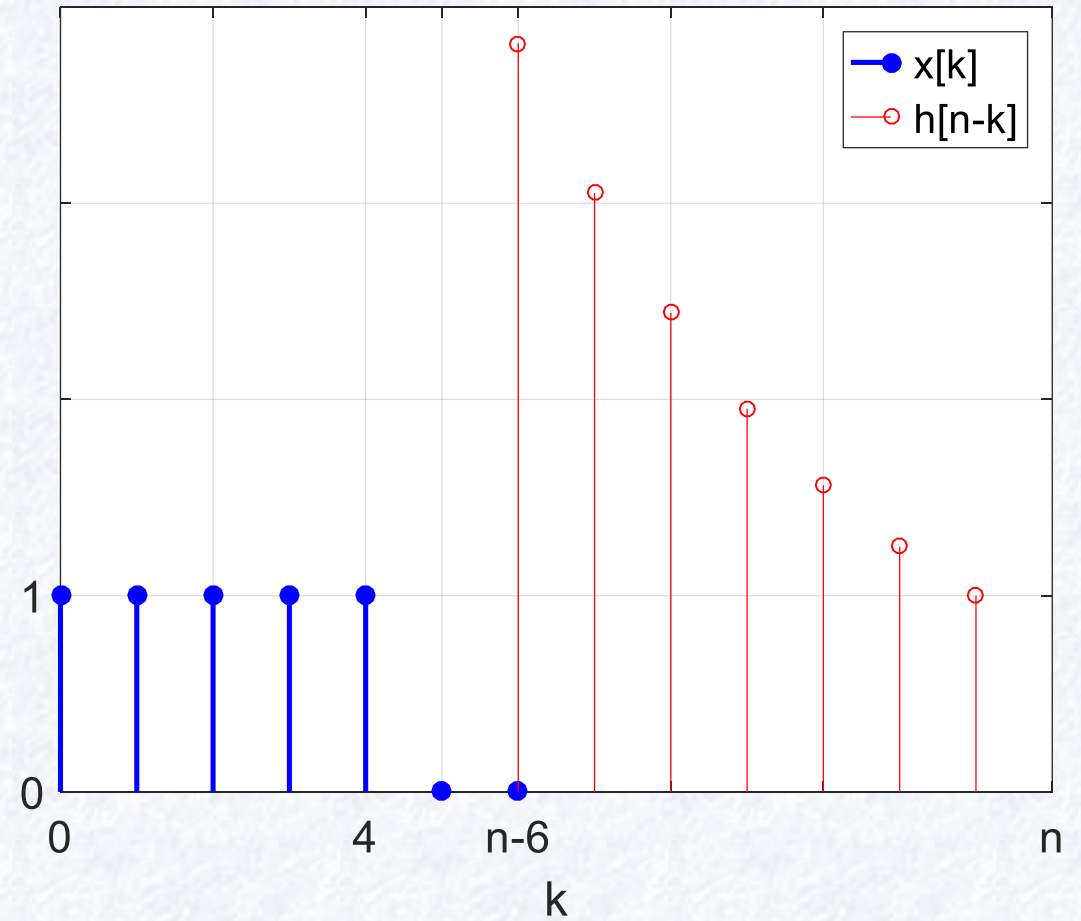
Örnek 2

- $10 < n$ iken



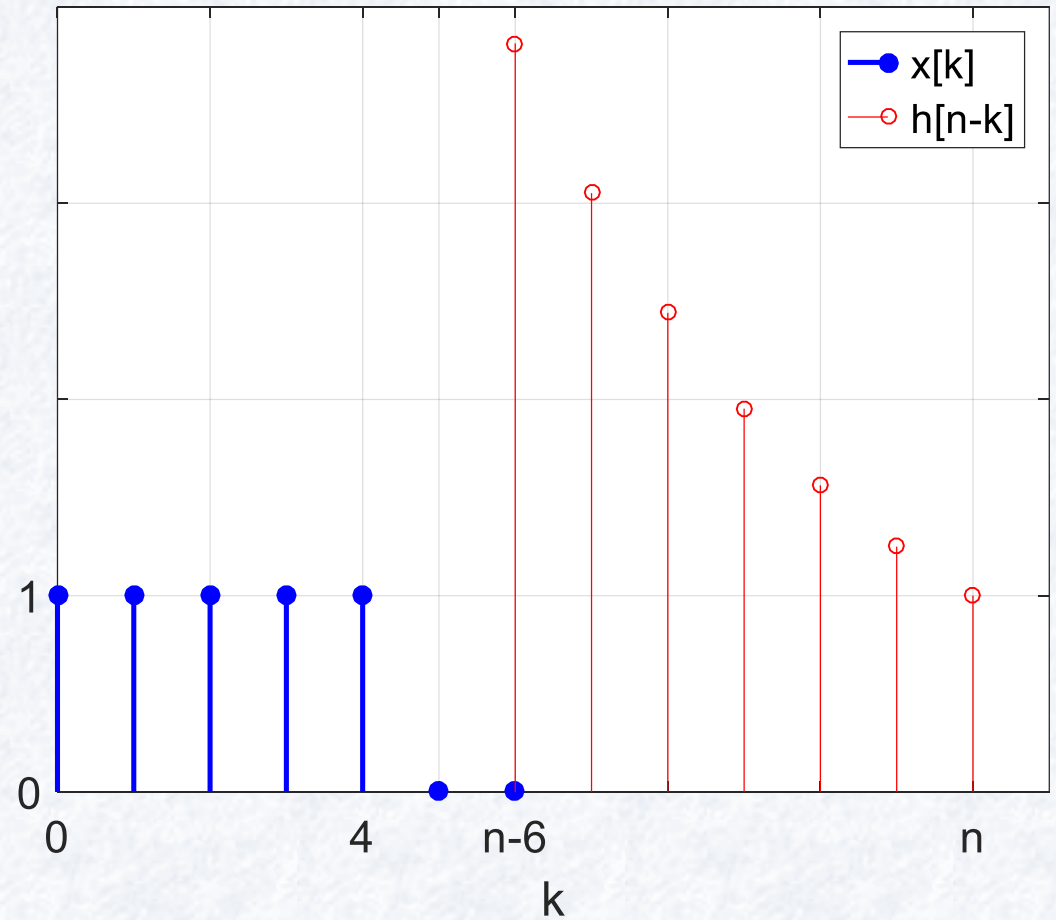
Örnek 2

- $10 < n$ iken
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Örnek 2

- $10 < n$ iken
 - ♦ Çakışma yok.
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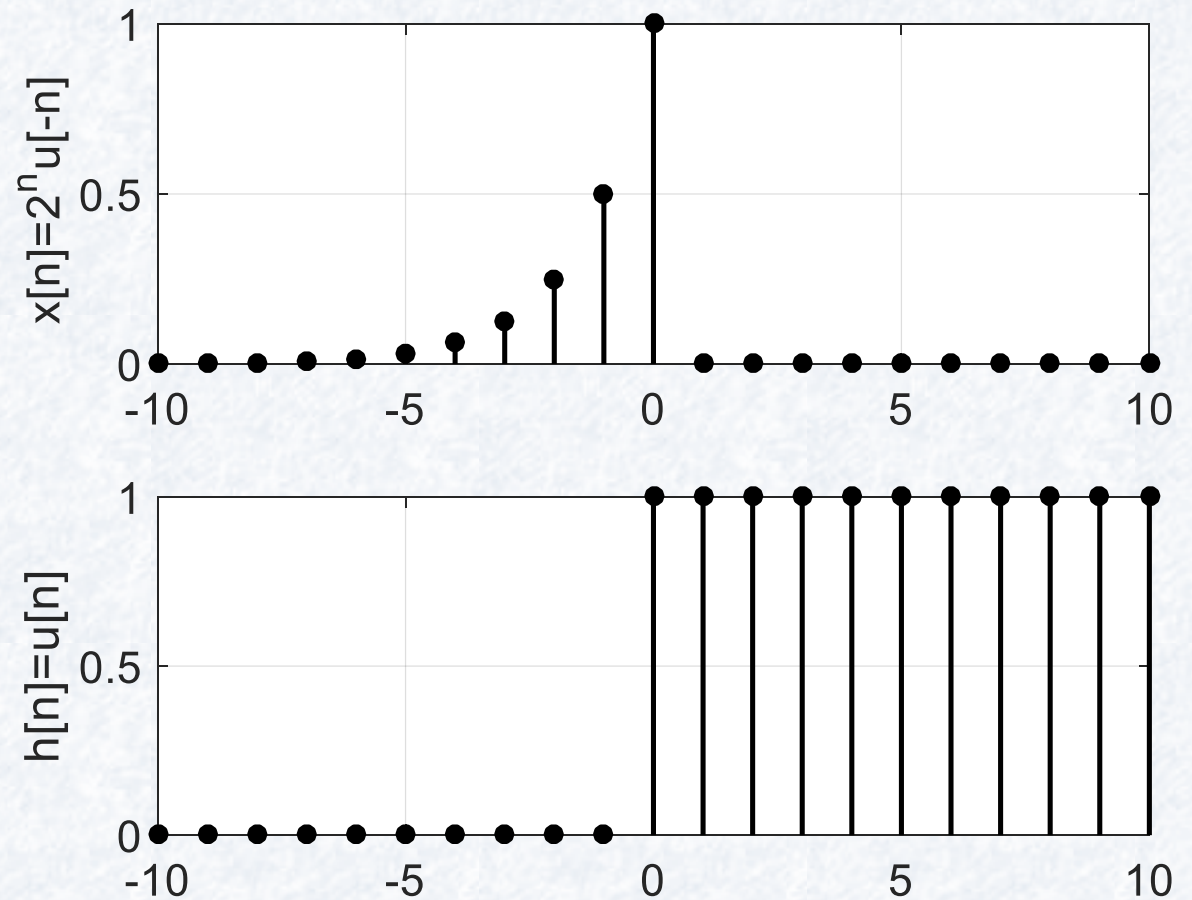


Örnek 2

- $n < 0$ iken $y[n] = 0$
- $0 \leq n \leq 4$ iken $y[n] = \alpha^n \frac{1 - \left(\frac{1}{\alpha}\right)^{n+1}}{1 - \frac{1}{\alpha}}$
- $4 < n \leq 6$ iken $y[n] = \alpha^n \frac{1 - \left(\frac{1}{\alpha}\right)^5}{1 - \frac{1}{\alpha}}$
- $6 < n \leq 10$ iken $y[n] = \alpha^6 \frac{1 - \left(\frac{1}{\alpha}\right)^{11-n}}{1 - \frac{1}{\alpha}}$
- $10 < n$ iken $y[n] = 0$

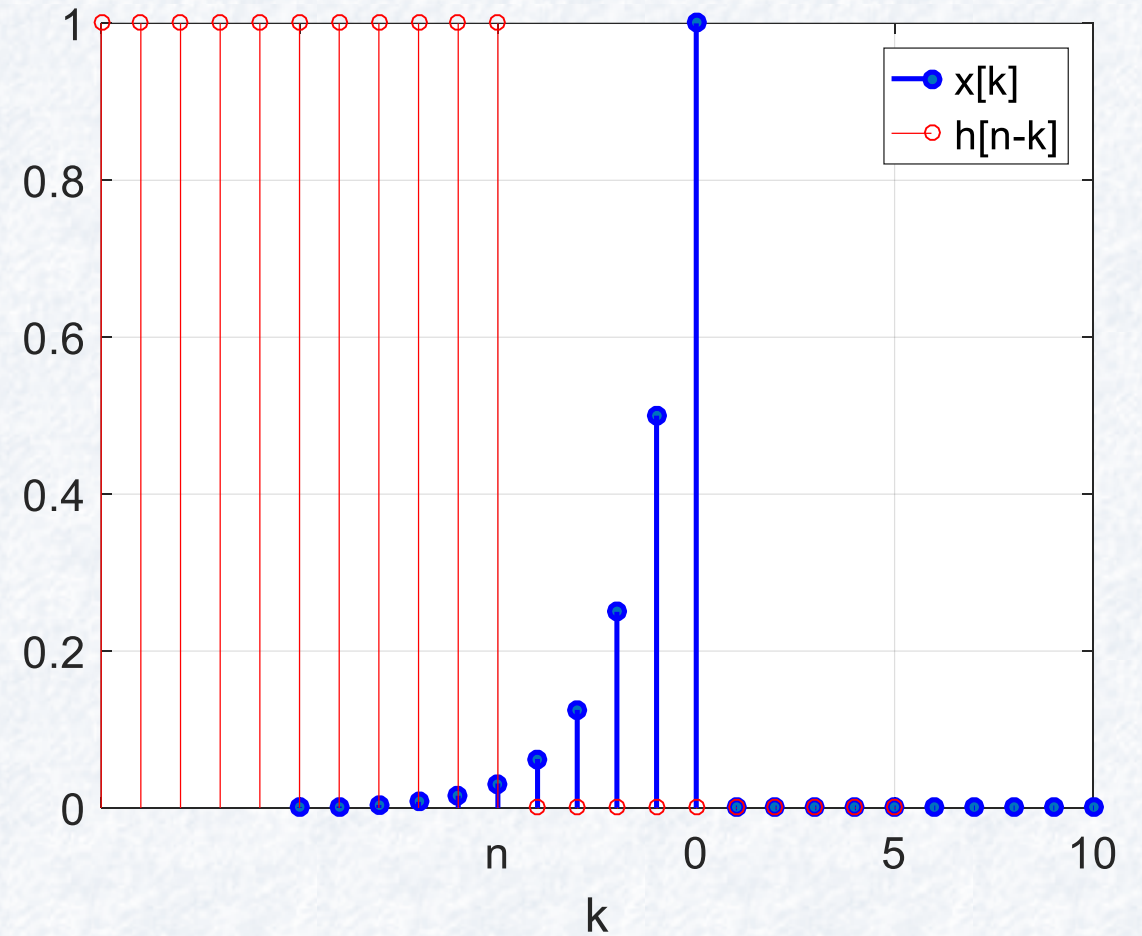
Örnek 3

- $x[n] = 2^n u[-n]$
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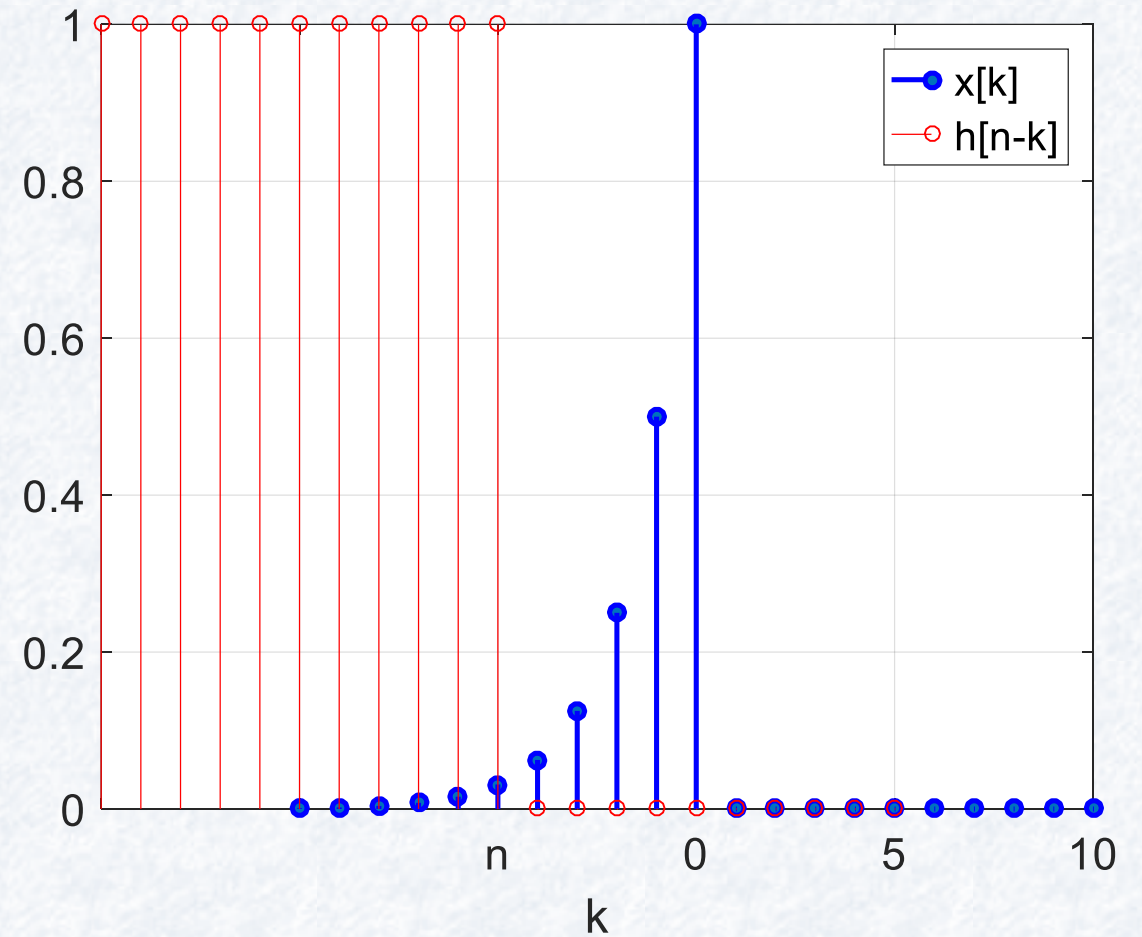
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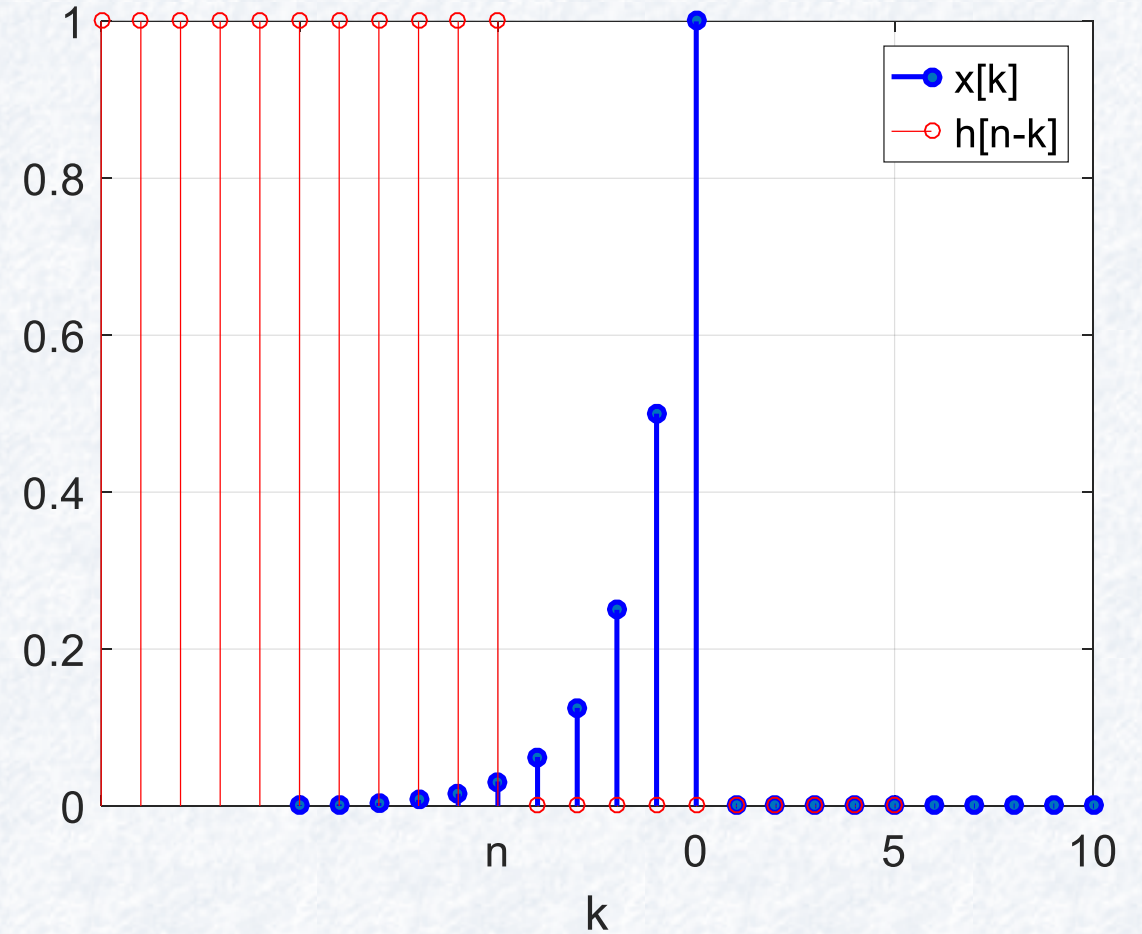
Örnek 3

- $x[n] = 2^n u[-n]$
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 - ♦ Çakışma, $-\infty - n$ arası



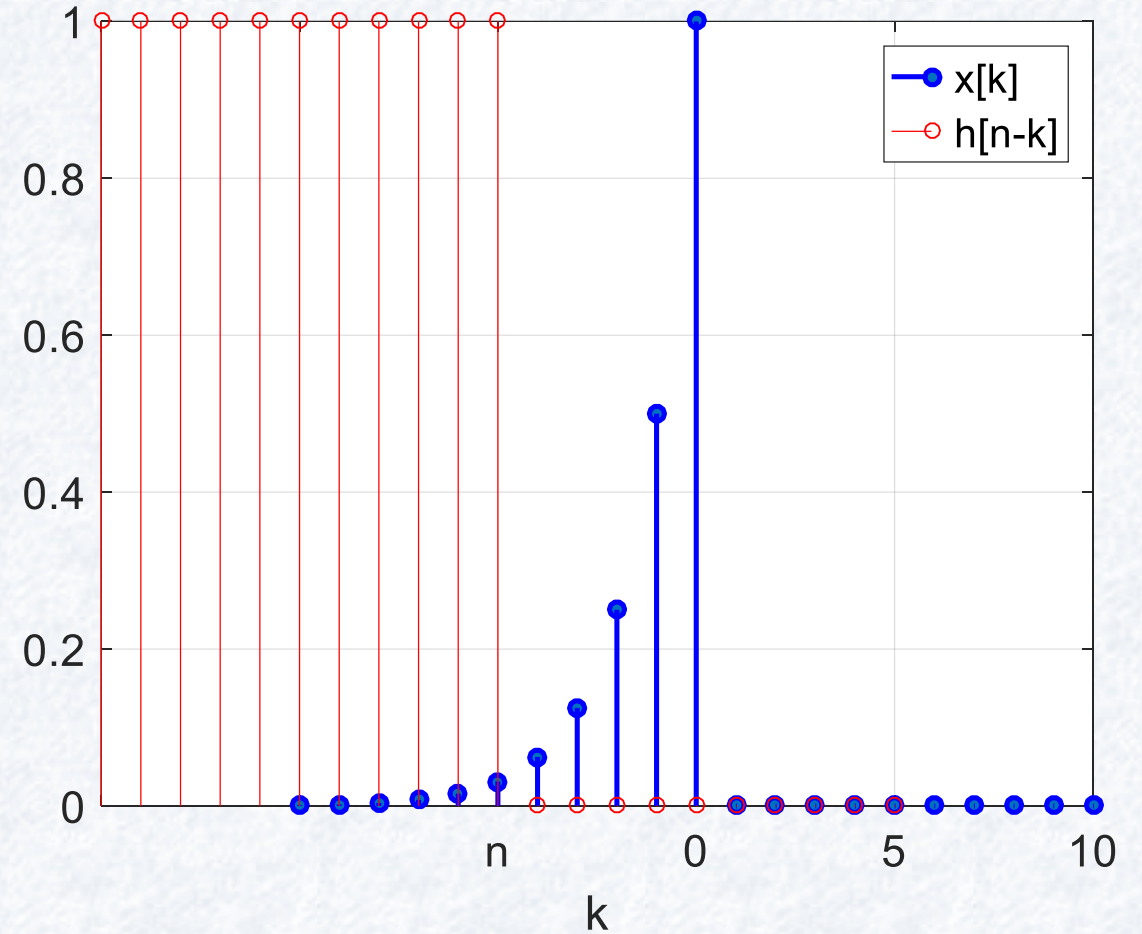
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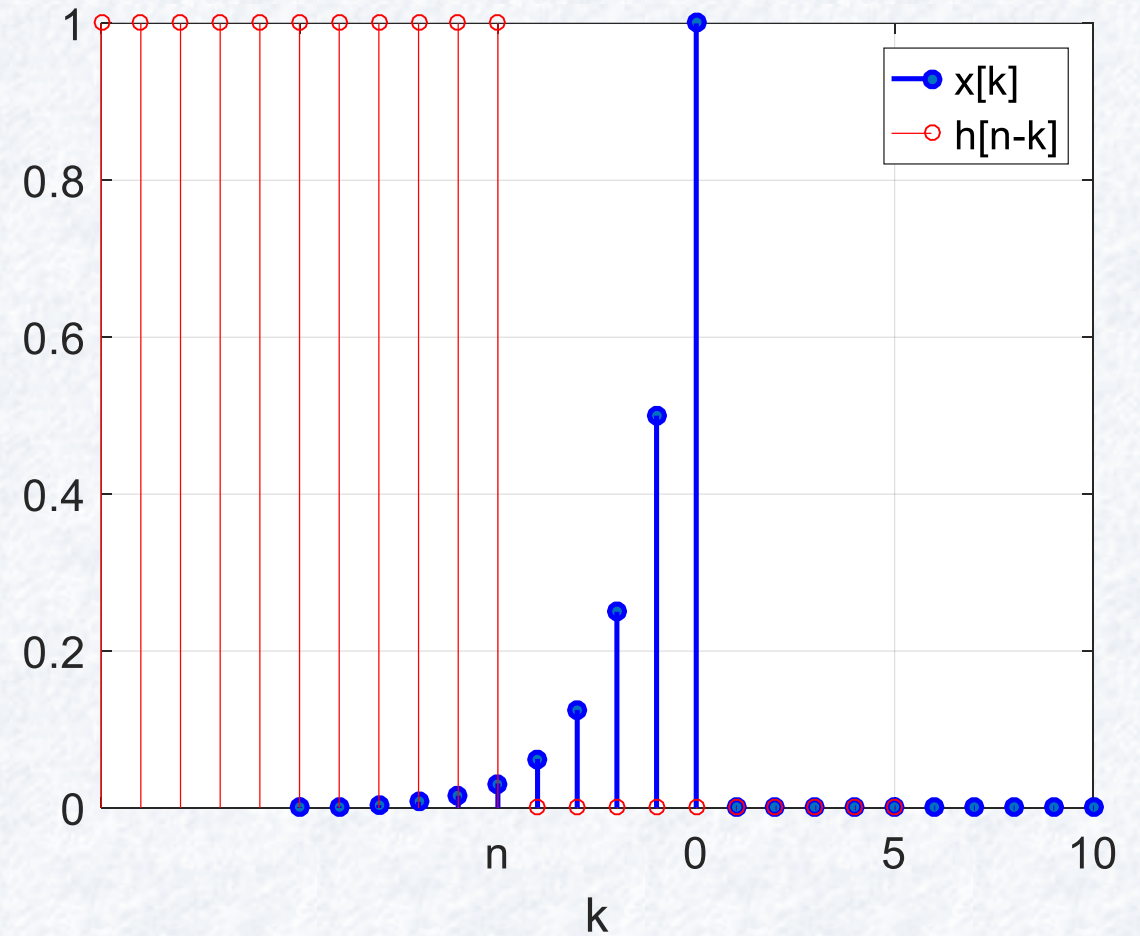
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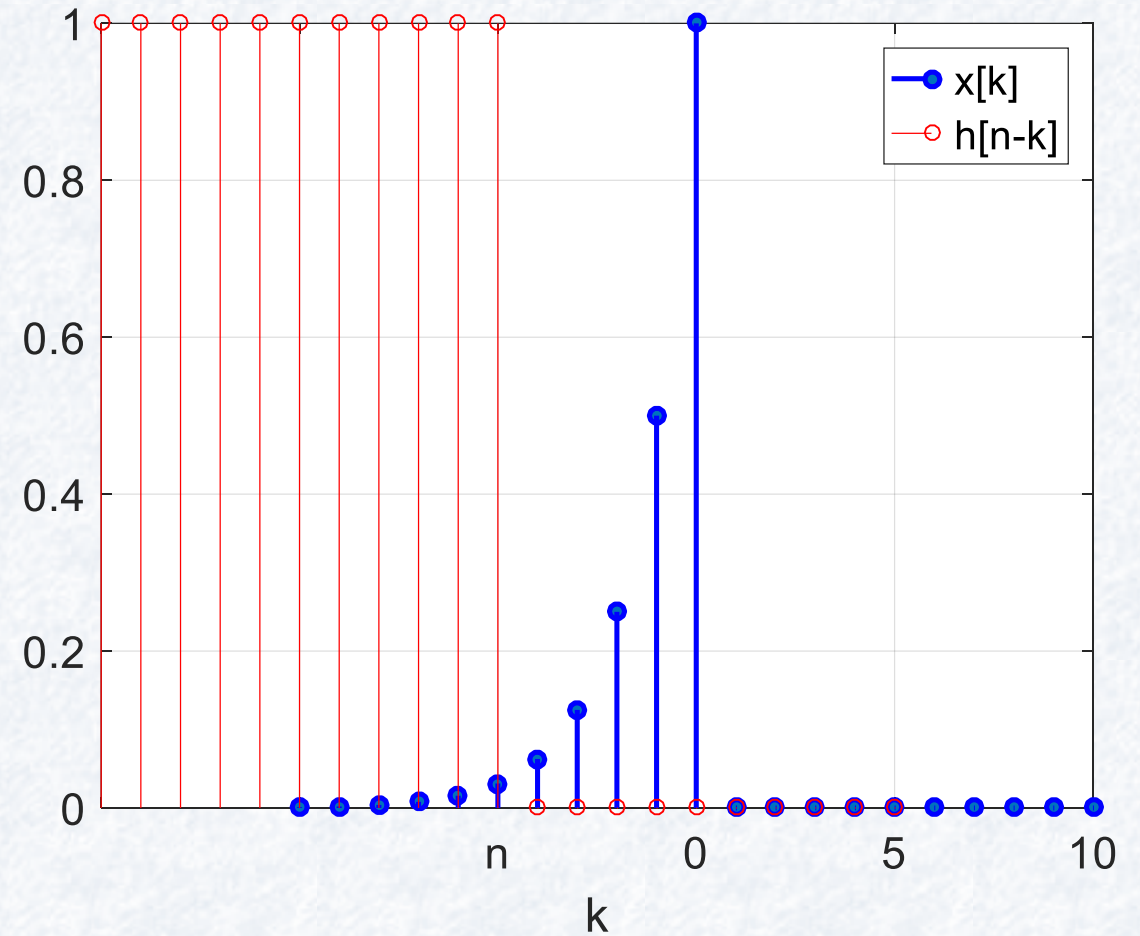
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 - ♦ $l = -k + n$



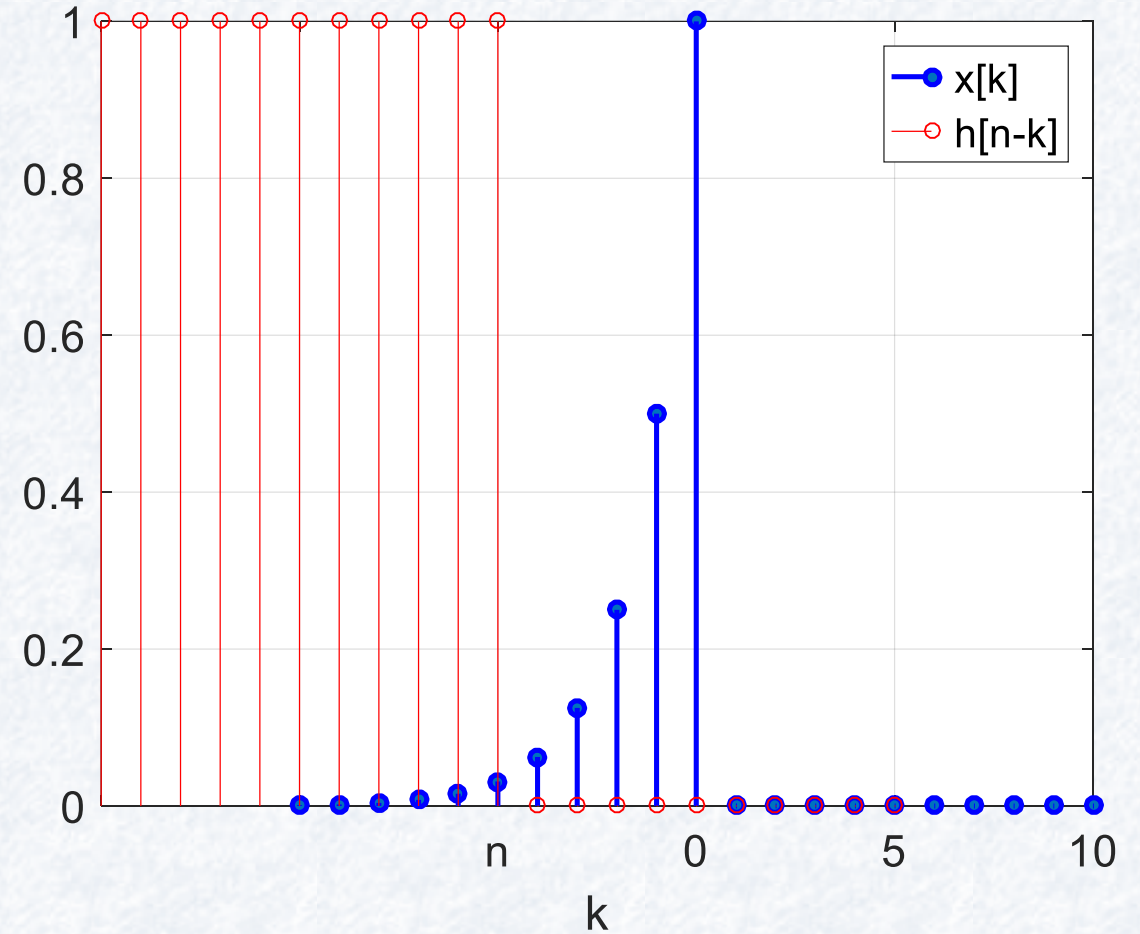
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- $y[n] = \sum_{k=-\infty}^n 2^k \mathbf{1}$
 - ♦ $l = -k + n$
- $y[n] = \sum_{l=\infty}^0 2^{n-l} \mathbf{1}$



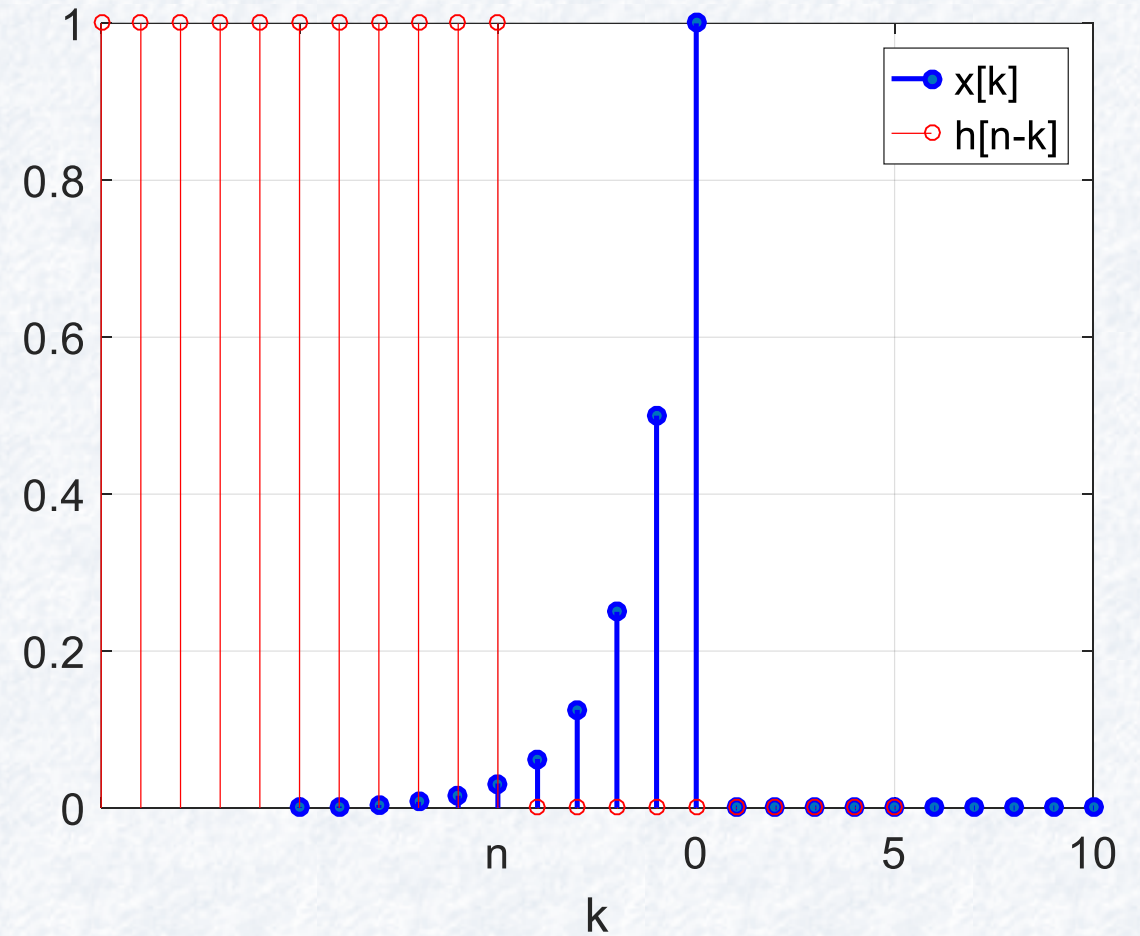
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 - ♦ $l = -k + n$
- $y[n] = \sum_{l=-\infty}^0 2^{n-l} \mathbf{1}$
- $y[n] = \sum_{l=0}^{\infty} 2^n 2^{-l} \mathbf{1}$



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- $n < 0$ iken
 - ♦ Çakışma, $-\infty - n$ arası
- $y[n] = \sum_{k=-\infty}^n x[k]h[n-k]$
- $y[n] = \sum_{k=-\infty}^n 2^k \mathbf{1}$
 - ♦ $l = -k + n$
- $y[n] = \sum_{l=-\infty}^0 2^{n-l} \mathbf{1}$
- $y[n] = \sum_{l=0}^{\infty} 2^n 2^{-l} \mathbf{1}$
- $y[n] = 2^n \sum_{l=0}^{\infty} \left(\frac{1}{2}\right)^l$



Örnek 3

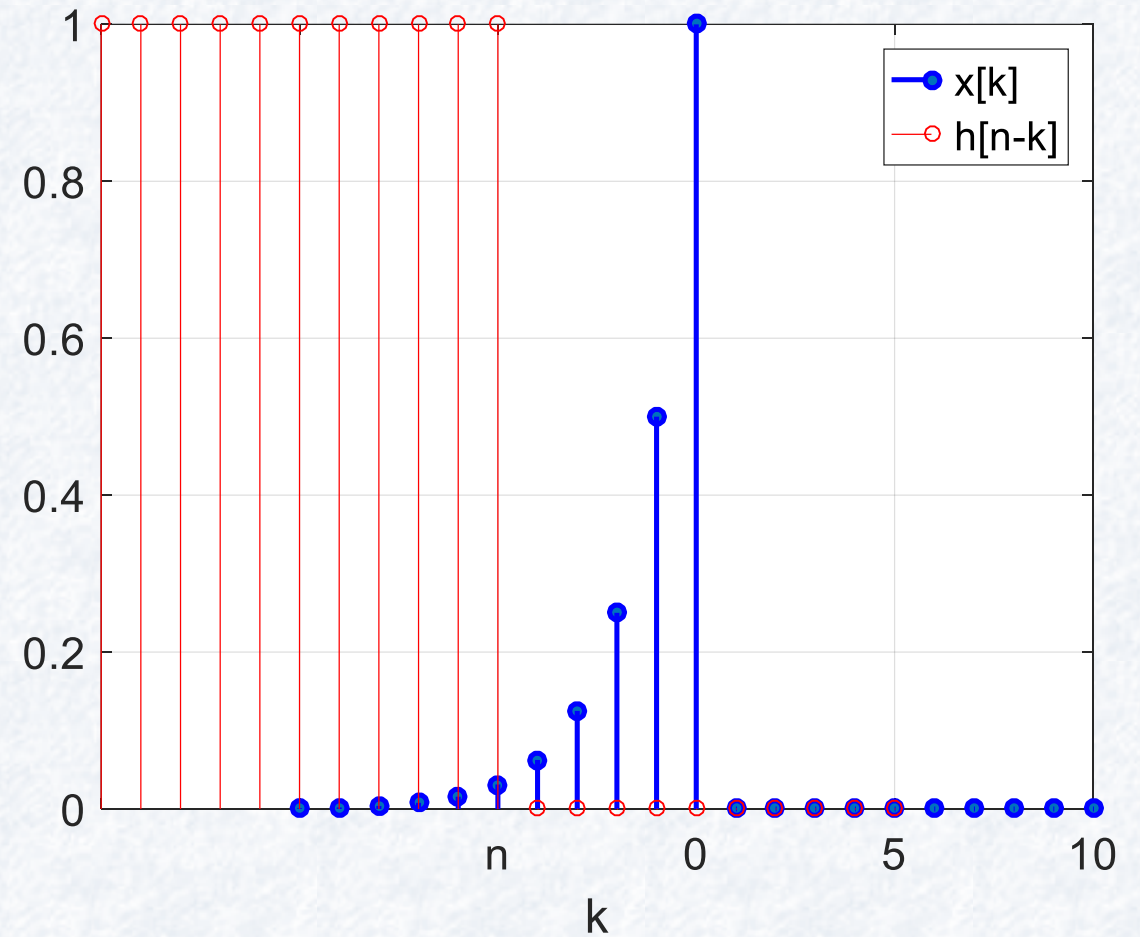
- $x[n] = 2^n u[-n]$

- $h[n] = u[n]$

- $n < 0$ iken

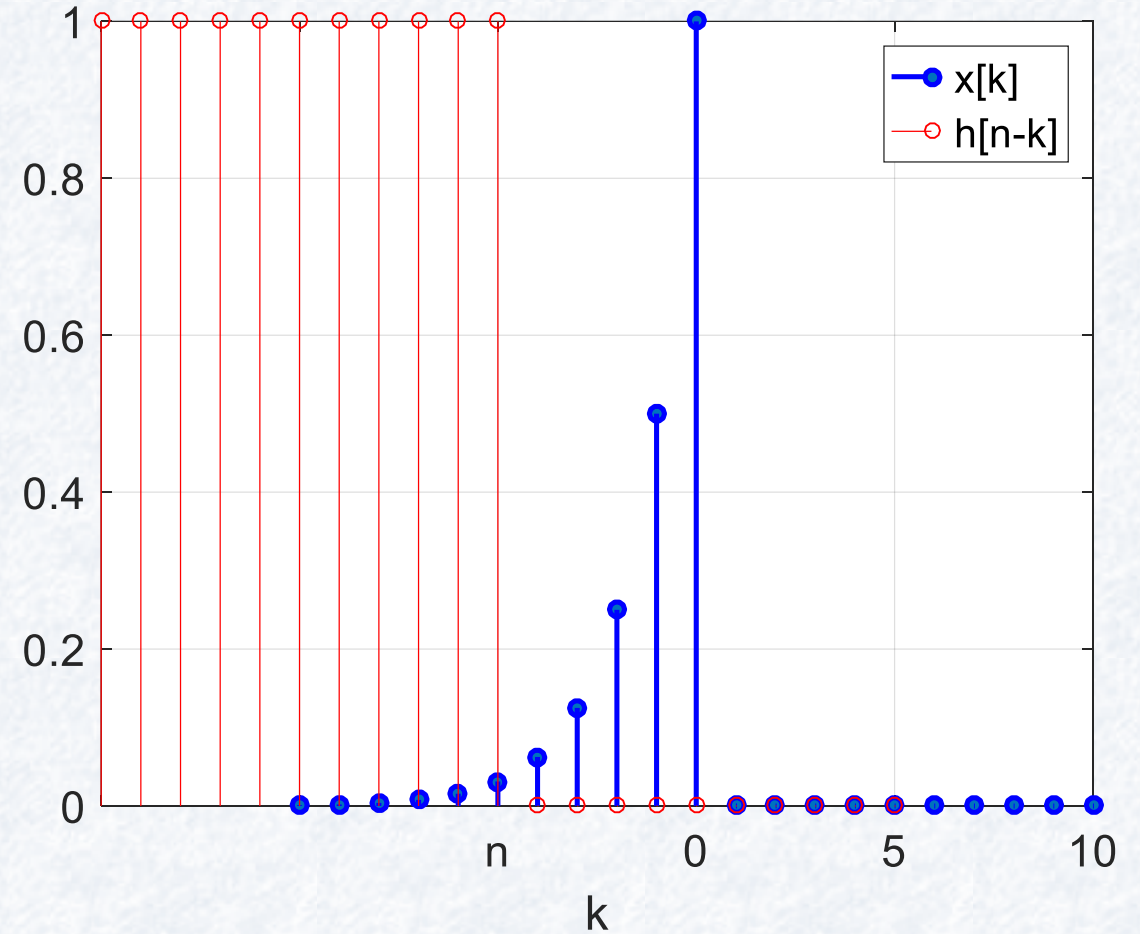
- $y[n] = 2^n \sum_{l=0}^{\infty} \left(\frac{1}{2}\right)^l$

$$\diamond \sum_{l=0}^{\infty} a^l = \begin{cases} \frac{1}{1-a}, & a < 1 \\ \infty, & a \geq 1 \end{cases}$$



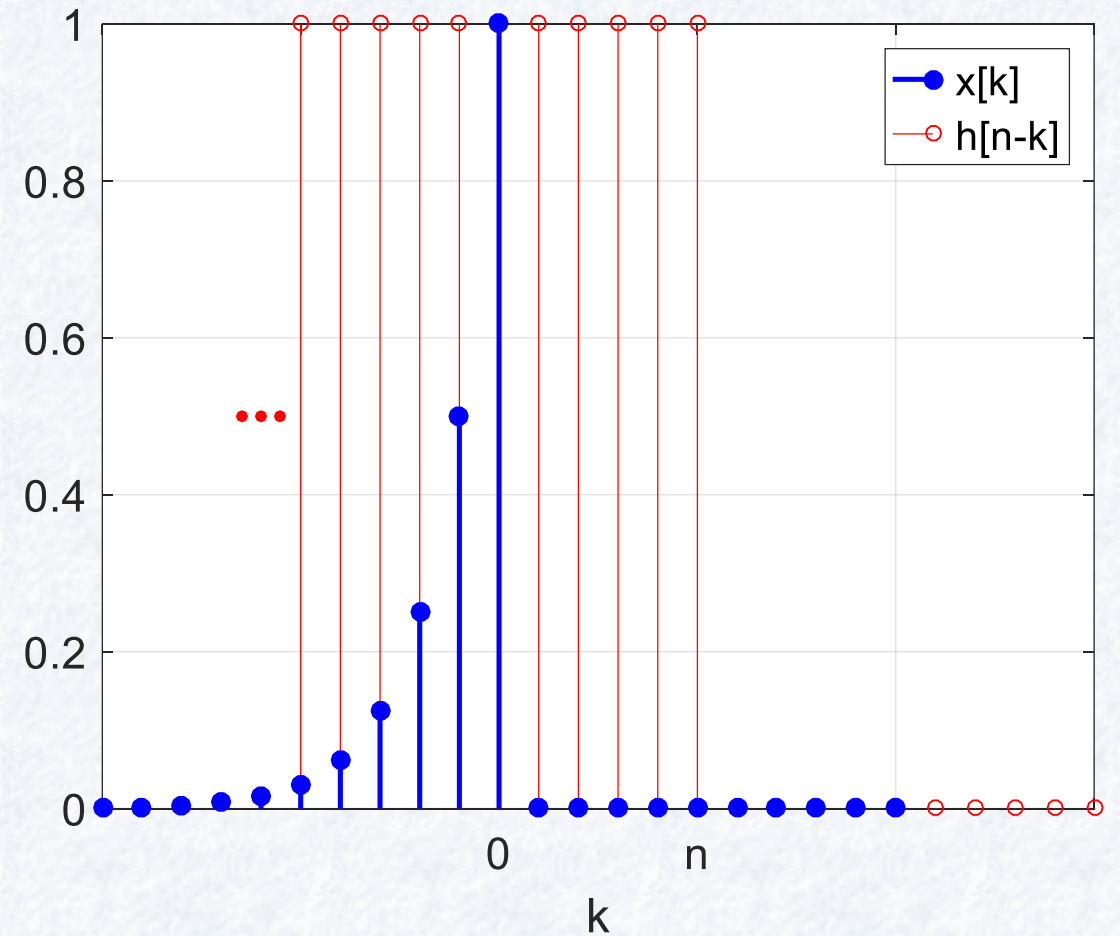
Örnek 3

- $x[n] = 2^n u[-n]$
- $h[n] = u[n]$
- $n < 0$ iken
- $y[n] = 2^n \sum_{l=0}^{\infty} \left(\frac{1}{2}\right)^l$
 - ♦ $\sum_{l=0}^{\infty} a^l = \begin{cases} \frac{1}{1-a}, & a < 1 \\ \infty, & a \geq 1 \end{cases}$
- $y[n] = 2^n \frac{1}{1-\frac{1}{2}} = 2^{n+1}$



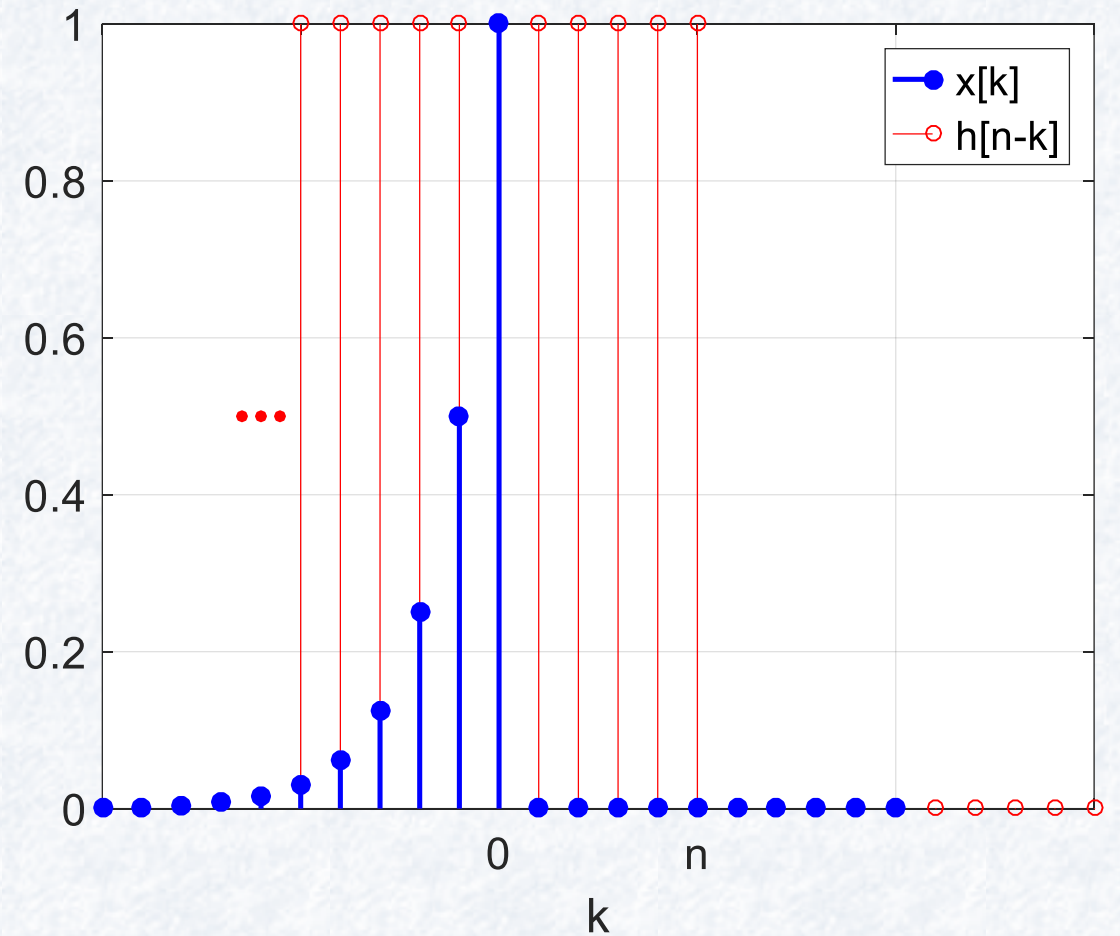
Örnek 3

- $x[n] = 2^n u[-n]$
- $h[n] = u[n]$
- $n \geq 0$ iken
 - ♦ Çakışma,



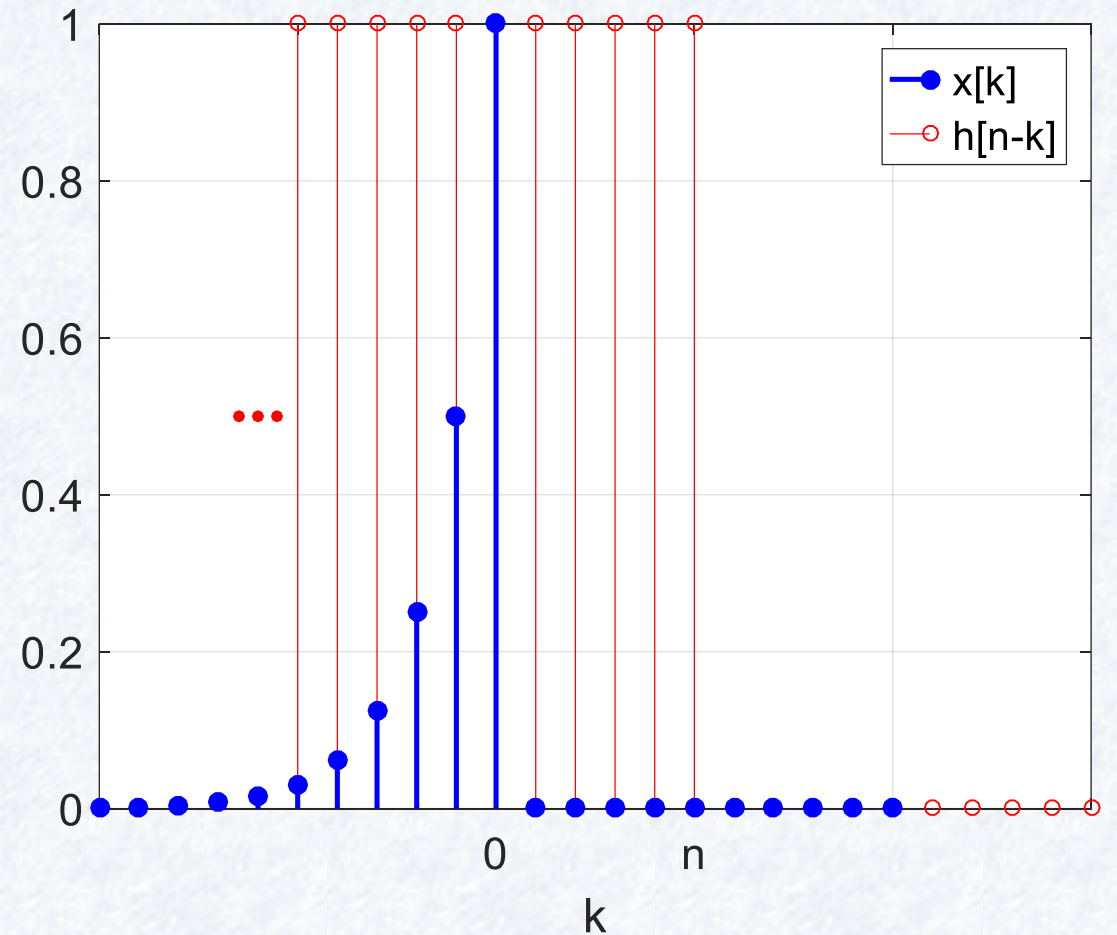
Örnek 3

- $x[n] = 2^n u[-n]$
- $h[n] = u[n]$
- $n \geq 0$ iken
 - ♦ Çakışma, $-\infty - 0$ arası



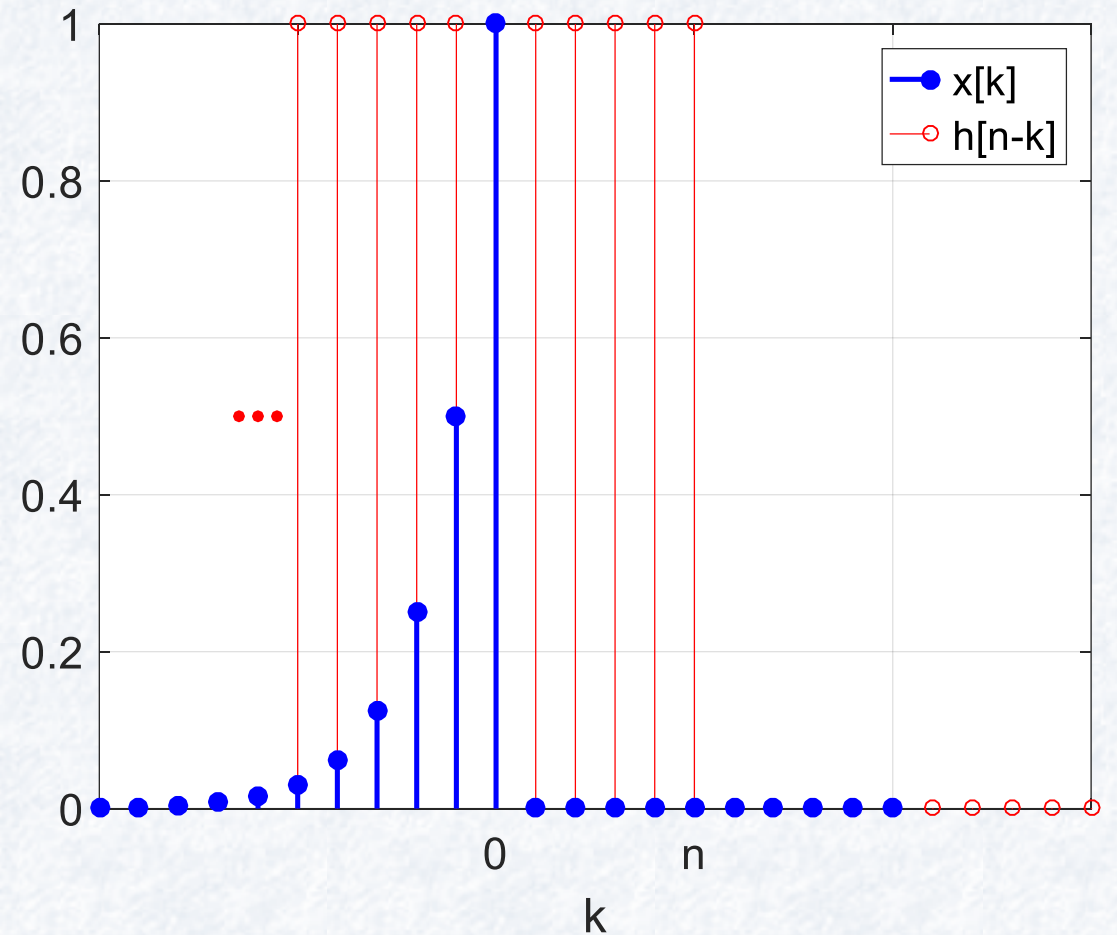
Örnek 3

- $x[n] = 2^n u[-n]$
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 - ♦ Çakışma, $-\infty - 0$ arası
- $y[n] = \sum_{k=-\infty}^0 x[k]h[n-k]$



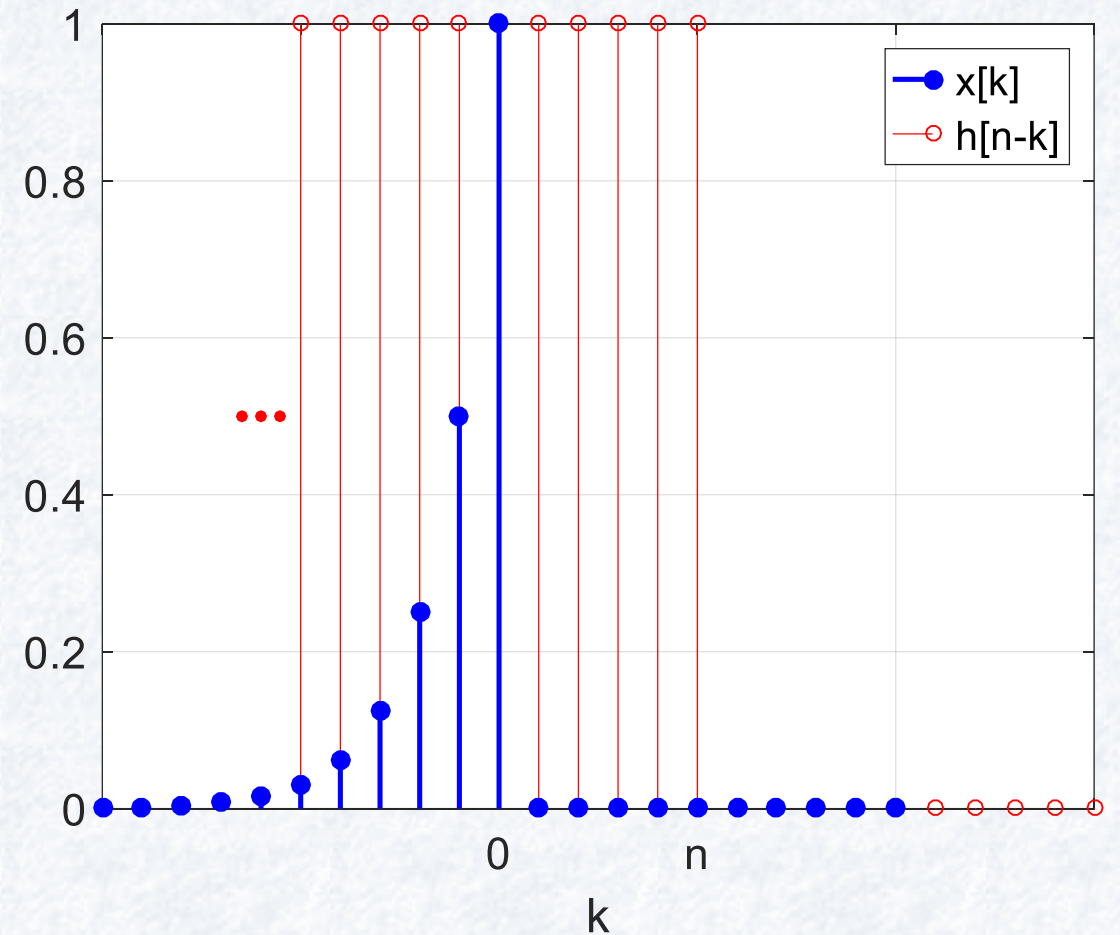
Örnek 3

- $x[n] = 2^n u[-n]$
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 - ♦ Çakışma, $-\infty - 0$ arası
- $y[n] = \sum_{k=-\infty}^0 x[k]h[n-k]$
- $y[n] = \sum_{k=-\infty}^0 2^k 1$



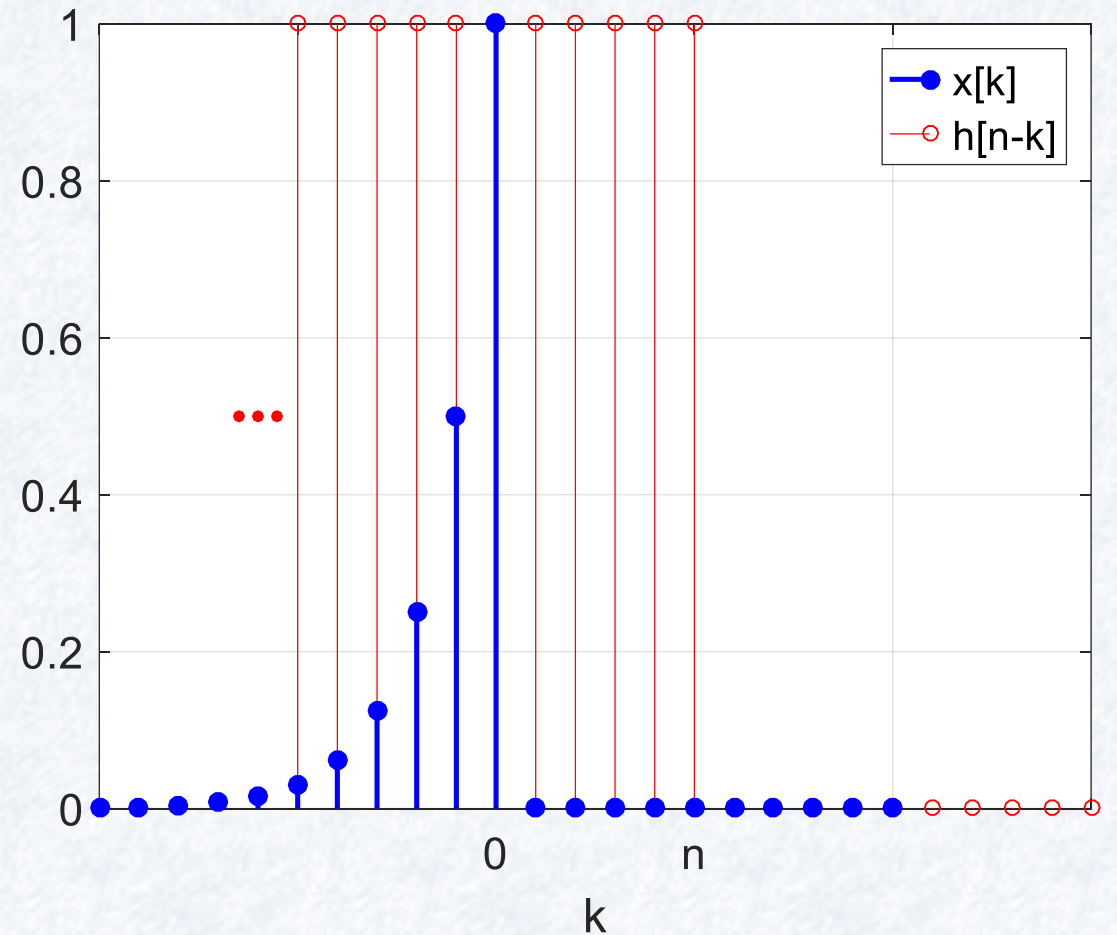
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 - ♦ $l = -k$



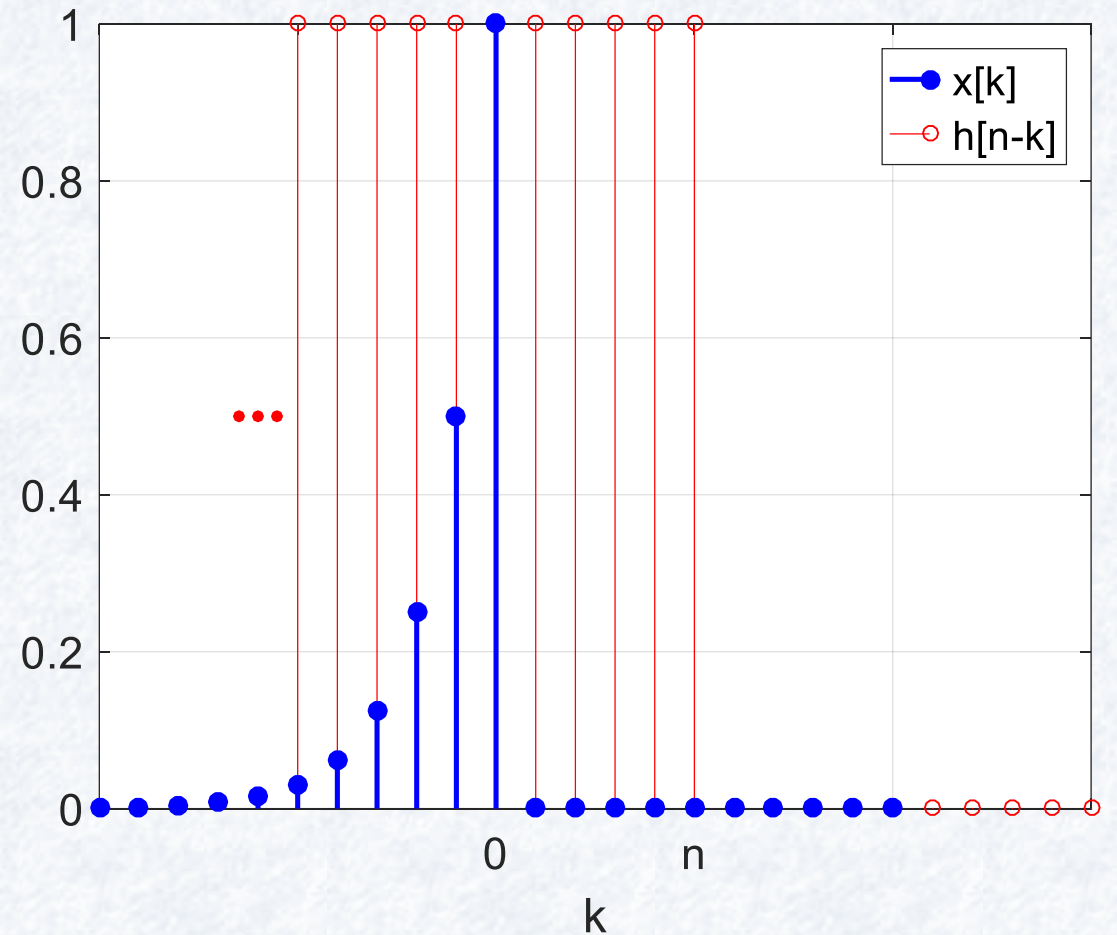
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- $x[n] = 2^n u[-n]$
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- $y[n] = \sum_{k=-\infty}^0 x[k]h[n-k]$
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 - ♦ $l = -k$
- $y[n] = \sum_{l=\infty}^0 2^{-l} \mathbf{1}$



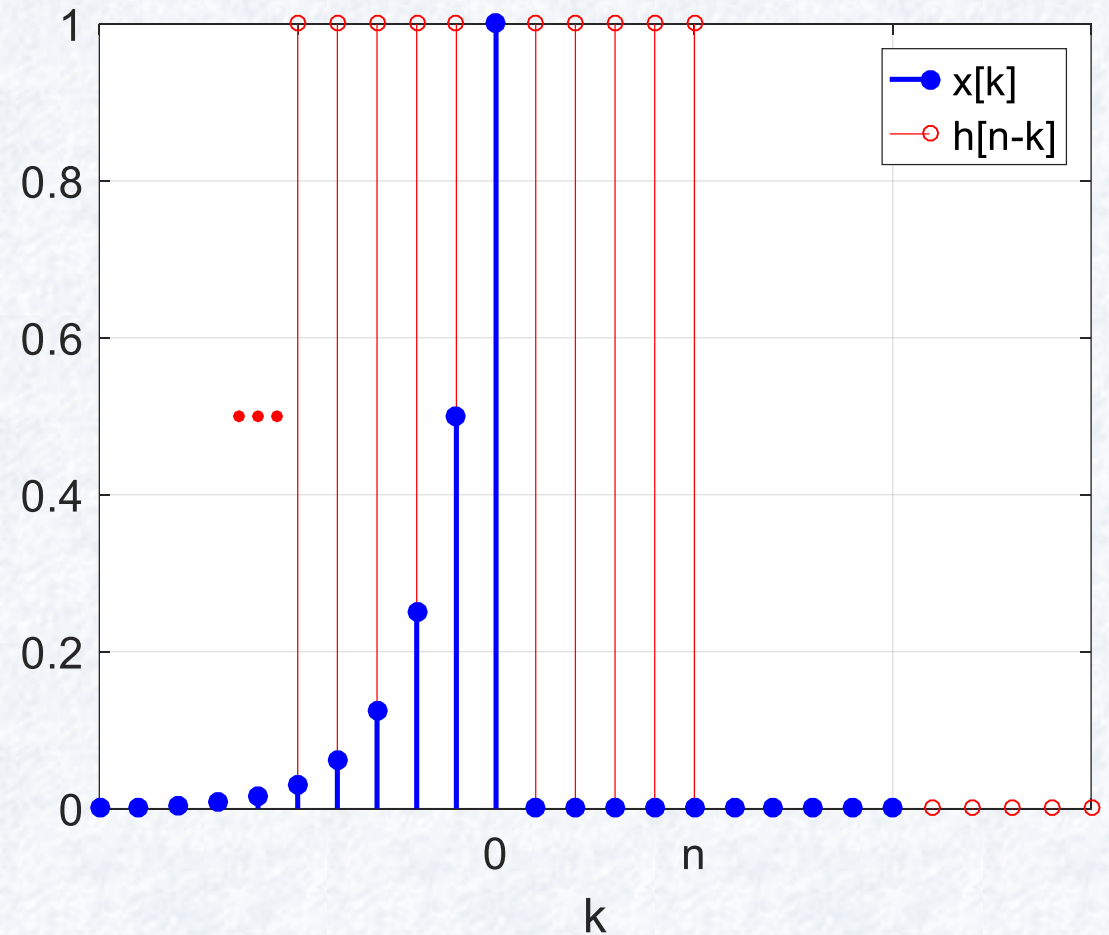
Örnek 3

- $x[n] = 2^n u[-n]$
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Örnek 3

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- $y[n] = \sum_{l=0}^{\infty} \left(\frac{1}{2}\right)^l = \frac{1}{1-\frac{1}{2}} = 2$



Örnek 3

- $x[n] = 2^n u[-n]$
- $h[n] = u[n]$
- $n < 0$ iken $y[n] = 2^n \frac{1}{1 - \frac{1}{2}} = 2^{n+1}$
- $n \geq 0$ iken $y[n] = \sum_{l=0}^{\infty} \left(\frac{1}{2}\right)^l = \frac{1}{1 - \frac{1}{2}} = 2$

Örnek 3

- $x[n] = 2^n u[-n]$
- $h[n] = u[n]$
- $n < 0$ iken $y[n] = 2^n \frac{1}{1 - \frac{1}{2}} = 2^{n+1}$
- $n \geq 0$ iken $y[n] = \sum_{l=0}^{\infty} \left(\frac{1}{2}\right)^l = \frac{1}{1 - \frac{1}{2}} = 2$
- $y[n] = 2^{n+1} u[-n - 1] + 2u[n]$

Konvolüsyon Özellikleri

- Değişme Özelliği
 - ♦ $x[n] * h[n] = h[n] * x[n]$

Konvolüsyon Özellikleri

- Değişme Özelliği

- ◆ $x[n] * h[n] = h[n] * x[n]$

- Dağılma Özelliği

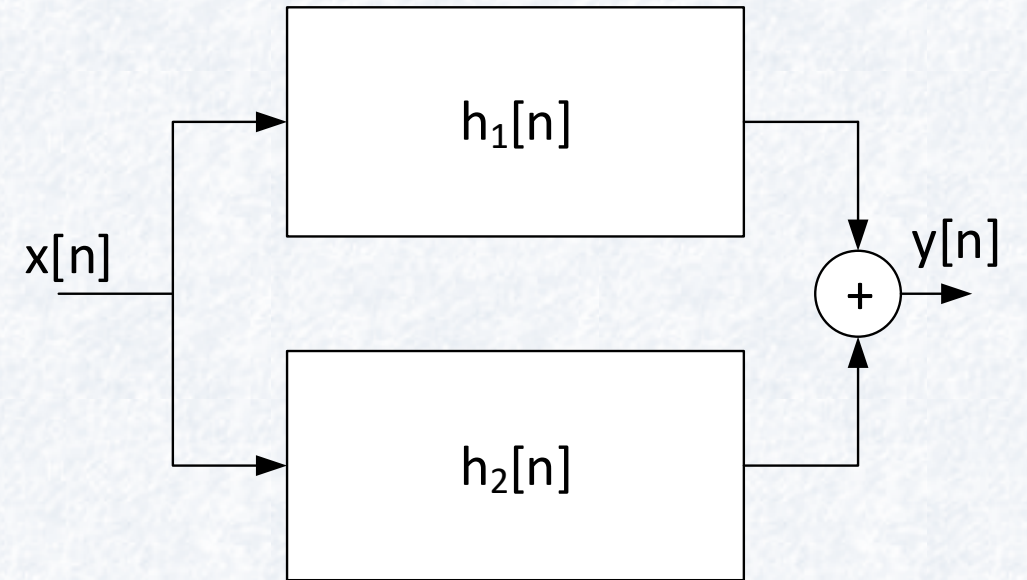
- ◆ $x[n] * (h_1[n] + h_2[n]) = x[n] * h_1[n] + x[n] * h_2[n]$

Konvolüsyon Özellikleri

- Değişme Özelliği
 - ♦ $x[n] * h[n] = h[n] * x[n]$
- Dağılma Özelliği
 - ♦ $x[n] * (h_1[n] + h_2[n]) = x[n] * h_1[n] + x[n] * h_2[n]$
- Birleşme Özelliği
 - ♦ $x[n] * (h_1[n] * h_2[n]) = (x[n] * h_1[n]) * h_2[n]$

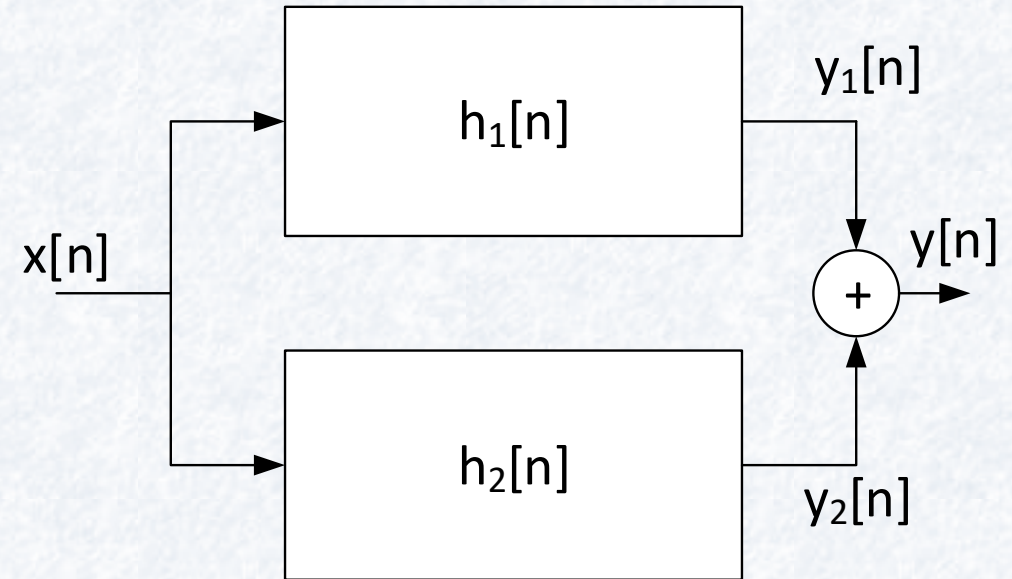
Konvolüsyon Özellikleri

- Dağılma Özelliği
- $y[n] = ?$



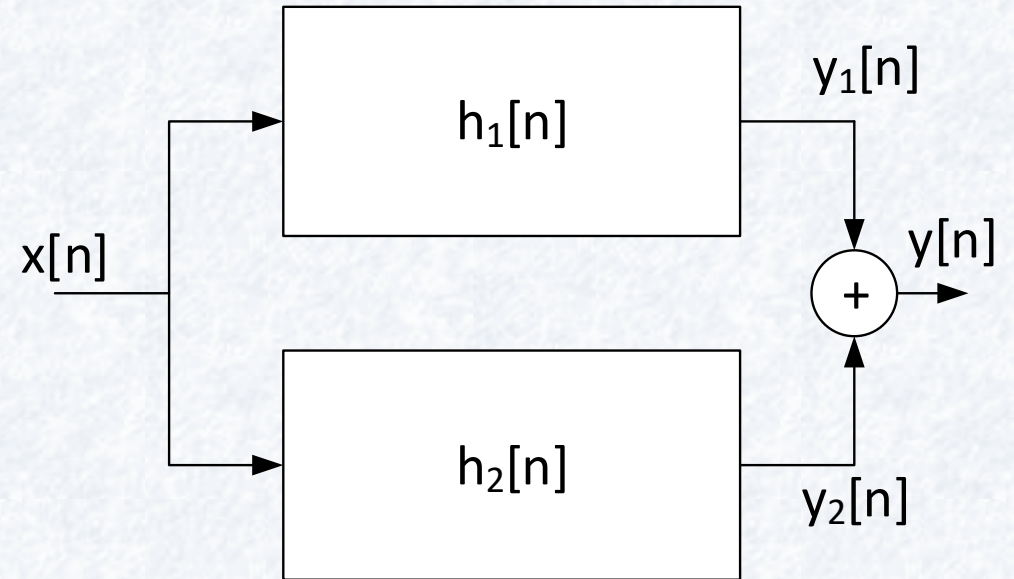
Konvolüsyon Özellikleri

- Dağılma Özelliği
- $y[n] = ?$
- $y[n] = y_1[n] + y_2[n]$
- $y_1[n] = ?$
- $y_2[n] = ?$



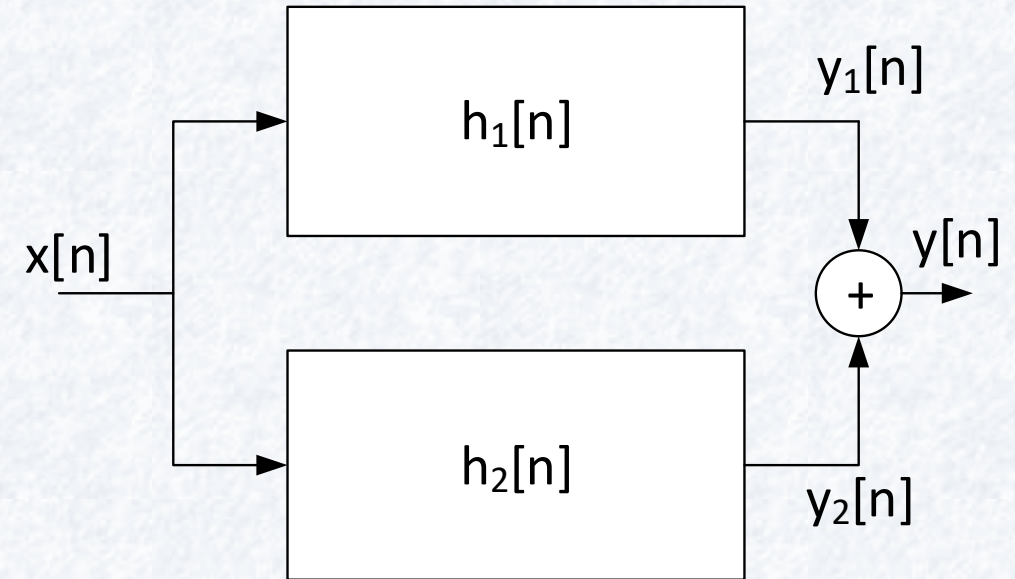
Konvolüsyon Özellikleri

- Dağılma Özelliği
- $y[n] = ?$
- $y[n] = y_1[n] + y_2[n]$
- $y_1[n] = x[n] * h_1[n]$
- $y_2[n] = x[n] * h_2[n]$



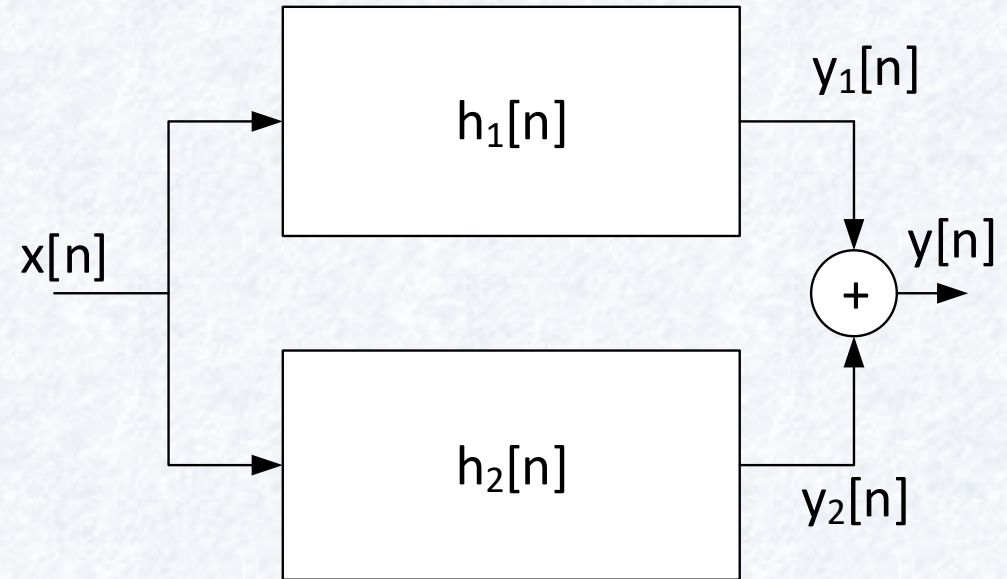
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- Dağılma Özelliği
- $y[n] = ?$
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- $y[n] = x[n] * h_1[n] + x[n] * h_2[n]$



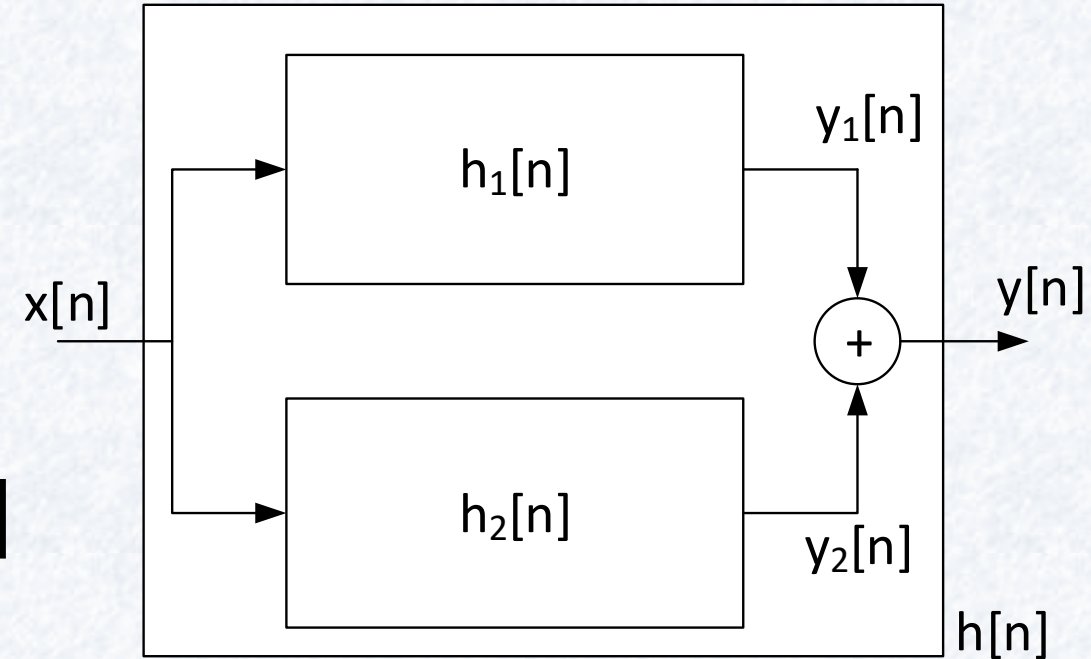
Konvolüsyon Özellikleri

- Dağılma Özelliği
- $y[n] = ?$
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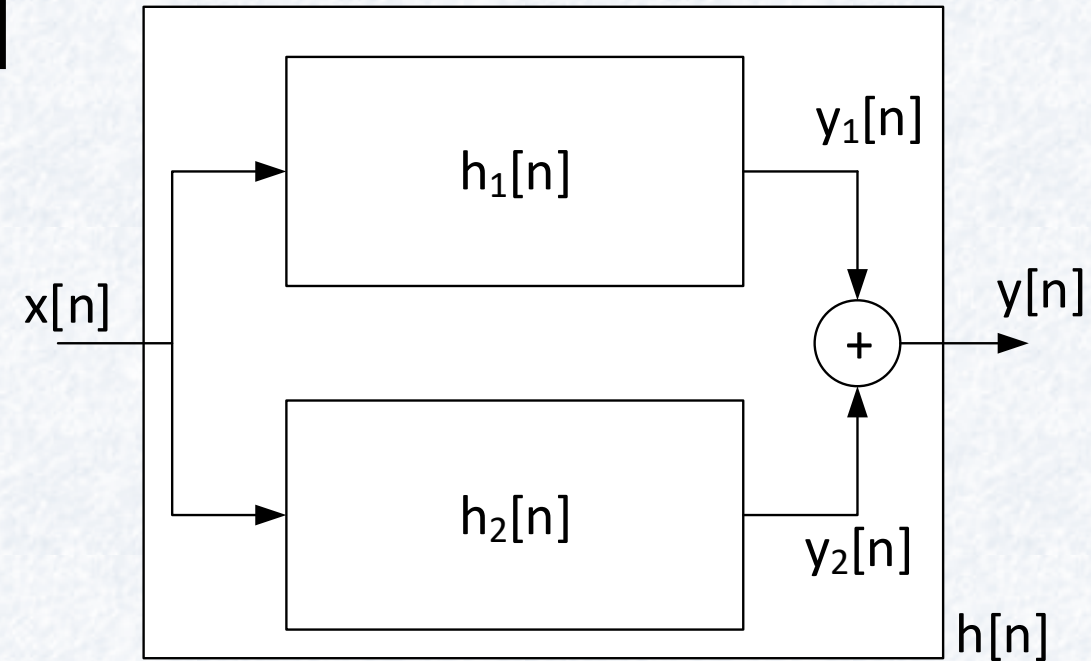
Konvolüsyon Özellikleri

- Dağılma Özelliği
- $y[n] = ?$
- $y[n] = y_1[n] + y_2[n]$
- $y_1[n] = x[n] * h_1[n]$
- $y_2[n] = x[n] * h_2[n]$
- $y[n] = x[n] * h_1[n] + x[n] * h_2[n]$
- $y[n] = x[n] * (h_1[n] + h_2[n])$
- $h[n] = ?$



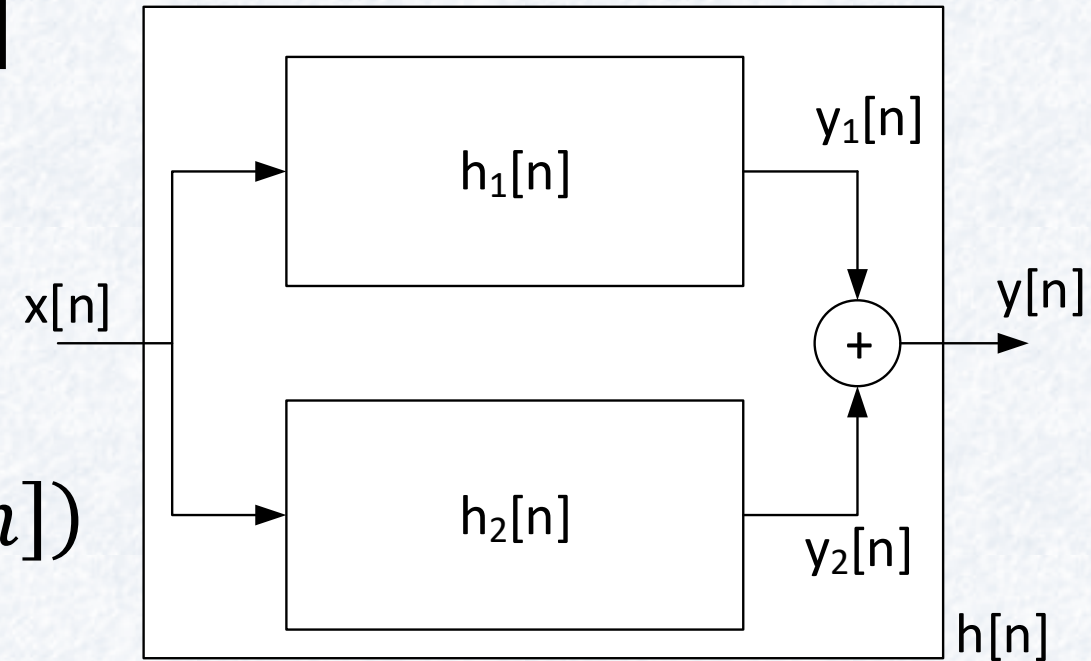
Konvolüsyon Özellikleri

- Dağılma Özelliği
- $y[n] = x[n] * h_1[n] + x[n] * h_2[n]$
- $y[n] = x[n] * (h_1[n] + h_2[n])$
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- $y[n] = x[n] * h[n]$



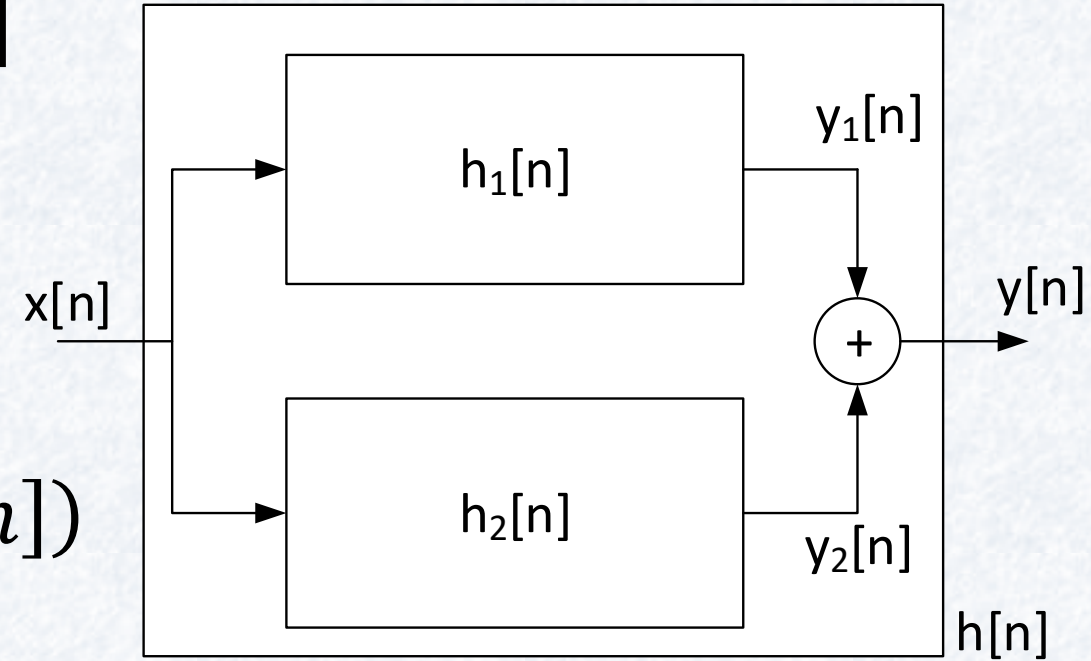
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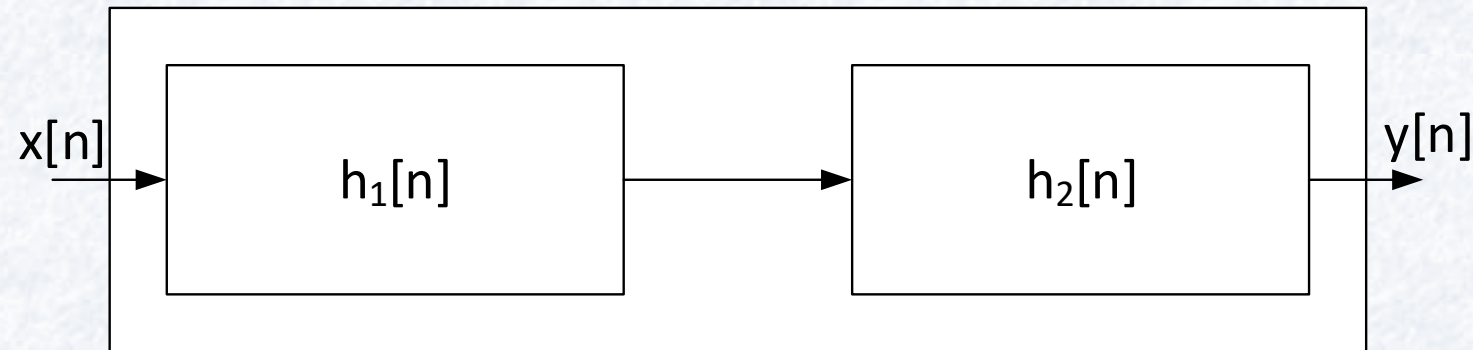
Konvolüsyon Özellikleri

- Dağılma Özelliği
- $y[n] = x[n] * h_1[n] + x[n] * h_2[n]$
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- $h[n] = ?$
- $y[n] = x[n] * h[n]$
- $x[n] * h[n] = x[n] * (h_1[n] + h_2[n])$
- $h[n] = (h_1[n] + h_2[n])$



Konvolüsyon Özellikleri

- Birleşme Özelliği
 - ♦ $x[n] * (h_1[n] * h_2[n]) = (x[n] * h_1[n]) * h_2[n]$
- $y[n] = ?$



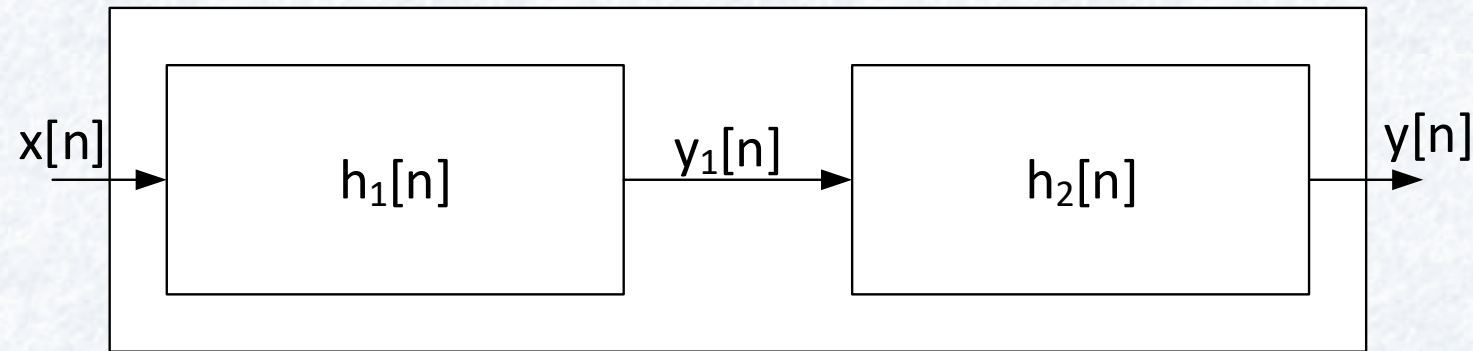
Konvolüsyon Özellikleri

- Birleşme Özelliği

- ♦ $x[n] * (h_1[n] * h_2[n]) = (x[n] * h_1[n]) * h_2[n]$

- $y[n] = y_1[n] * h_2[n]$

- $y_1[n] = ?$



Konvolüsyon Özellikleri

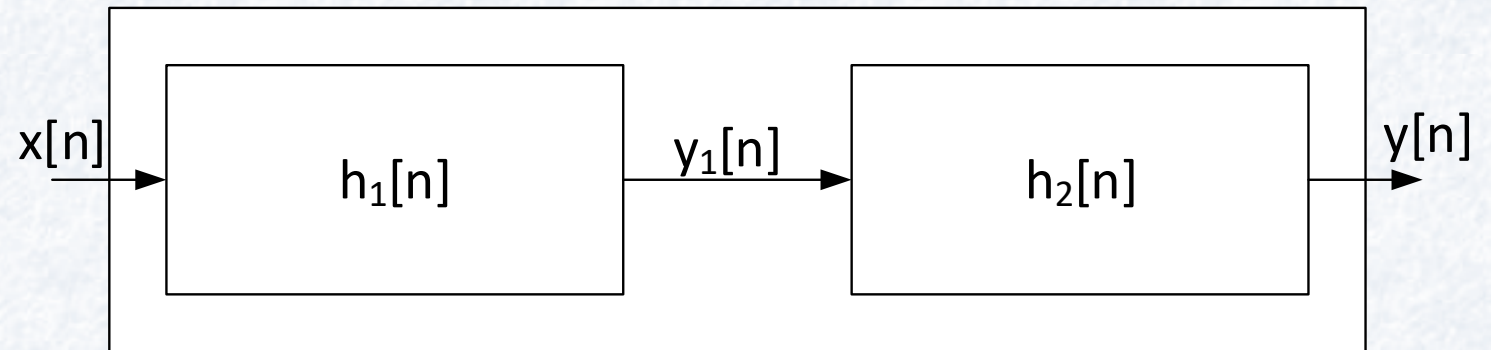
- Birleşme Özelliği

- ◆ $x[n] * (h_1[n] * h_2[n]) = (x[n] * h_1[n]) * h_2[n]$

- $y[n] = y_1[n] * h_2[n]$

- $y_1[n] = x[n] * h_1[n]$

- $y[n] = ?$



Konvolüsyon Özellikleri

- Birleşme Özelliği

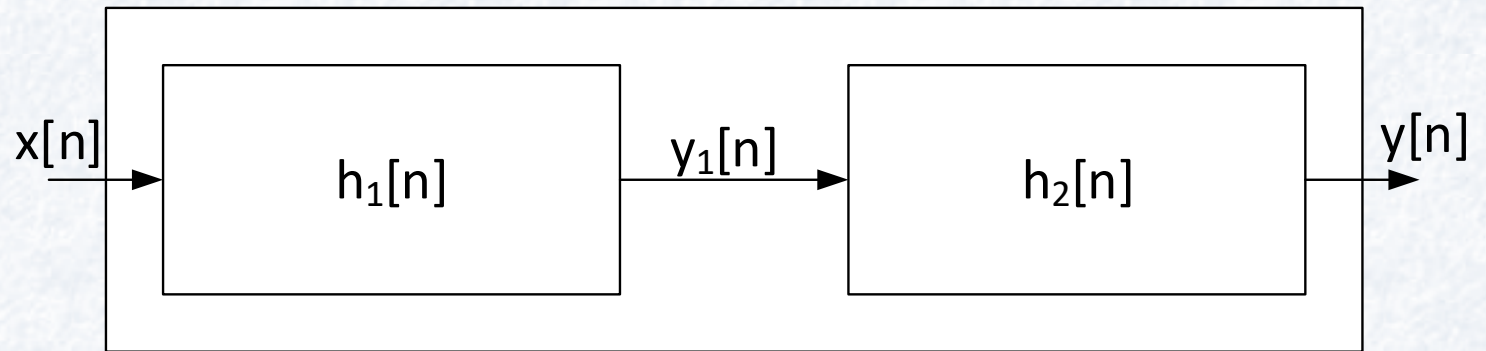
- ◆ $x[n] * (h_1[n] * h_2[n]) = (x[n] * h_1[n]) * h_2[n]$

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- $y_1[n] = x[n] * h_1[n]$

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Konvolüsyon Özellikleri

- Birleşme Özelliği

- ◆ $x[n] * (h_1[n] * h_2[n]) = (x[n] * h_1[n]) * h_2[n]$

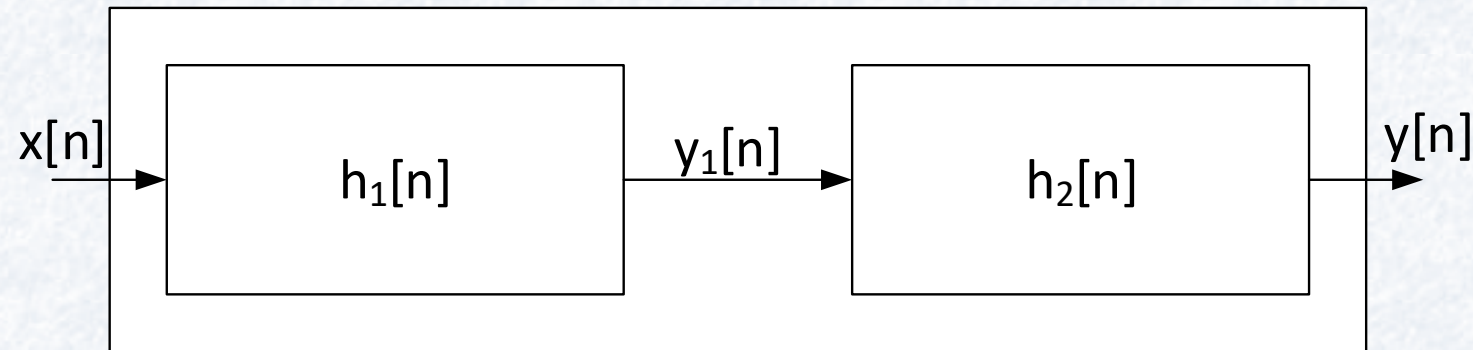
- $y[n] = y_1[n] * h_2[n]$

- $y_1[n] = x[n] * h_1[n]$

- $y[n] = x[n] * h_1[n] * h_2[n]$

- $h[n] = ?$

- $y[n] = x[n] * h[n]$



Konvolüsyon Özellikleri

- Birleşme Özelliği

- ♦ $x[n] * (h_1[n] * h_2[n]) = (x[n] * h_1[n]) * h_2[n]$

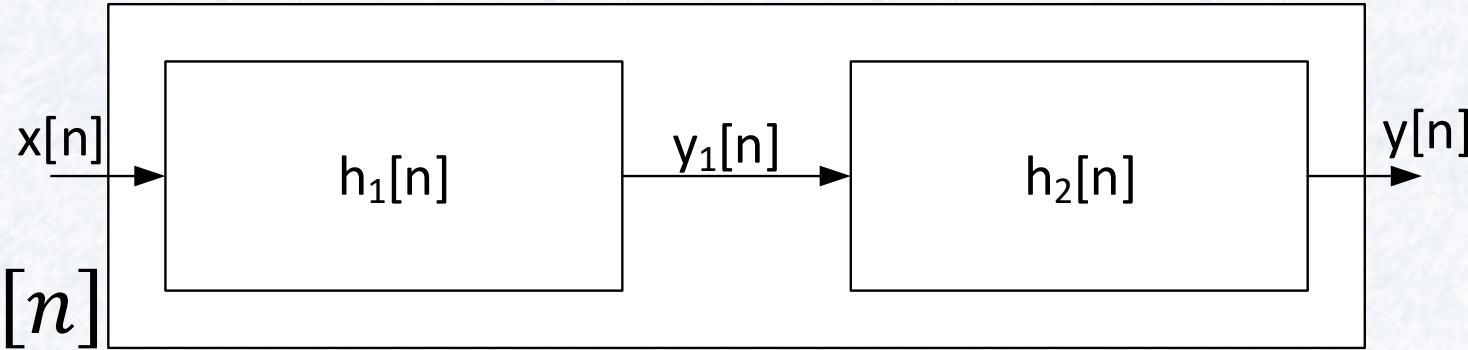
- $y[n] = y_1[n] * h_2[n]$

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Konvolüsyon Özellikleri

- Birleşme Özelliği

- ♦ $x[n] * (h_1[n] * h_2[n]) = (x[n] * h_1[n]) * h_2[n]$

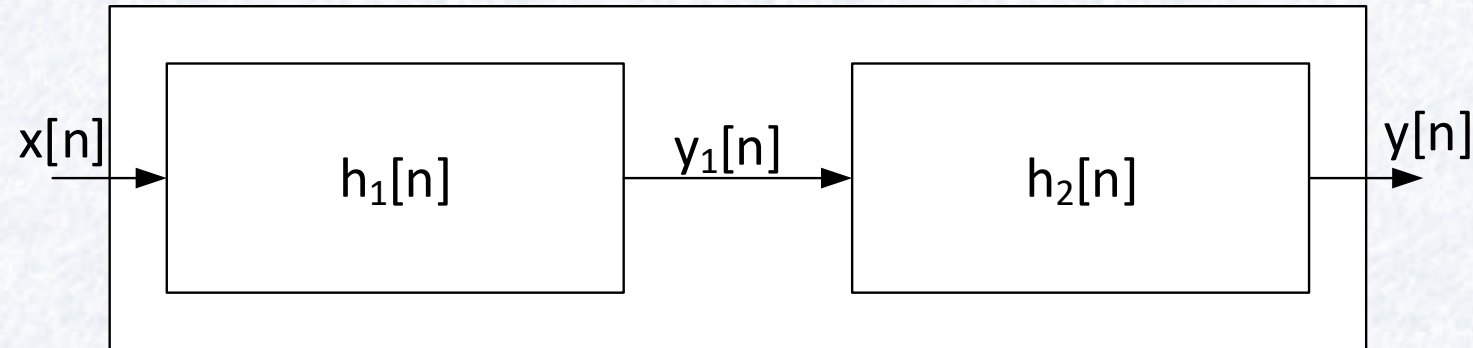
- $y[n] = y_1[n] * h_2[n]$

- $y_1[n] = x[n] * h_1[n]$

- $y[n] = x[n] * h_1[n] * h_2[n]$

- $y[n] = x[n] * h[n] = x[n] * h_1[n] * h_2[n]$

- $h[n] = h_1[n] * h_2[n]$



Sistem Özellikleri

- Hafızalılık
- Hafızasız
 - ♦ Sistem çıkışının, giriş işaretinin zamanın sadece o andaki bilgisine bağlı olması
- Hafızalı
 - ♦ Sistem çıkışının, giriş işaretinin ötelenmiş hallerine bağlı olması
- $y[n] = \sum_{k=-\infty}^{\infty} x[k]h[n-k] = \sum_{k=-\infty}^{\infty} h[k]x[n-k]$
- $y[n] = \cdots + h[-1]x[n+1] + h[0]x[n] + h[1]x[n-1] + \cdots$

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 - ♦ Hafızasız: $y[n]$, sadece $x[n]$ 'ye bağlı olması

Sistem Özellikleri

- Hafızalılık

- $y[n] = \cdots + h[-1]x[n+1] + h[0]x[n] + h[1]x[n-1] + \cdots$

- ♦ Hafızasız: $y[n]$, sadece $x[n]$ 'ye bağlı olması

- $y[n] = \underbrace{\cdots + h[-1]x[n+1] + h[0]x[n]}_0 + \underbrace{h[1]x[n-1] + \cdots}_0$

- $\forall n \neq 0$ iken $h[n] = 0$ olursa Hafızasız.

Sistem Özellikleri

- **Hafızalılık**
- $y[n] = \cdots + h[-1]x[n+1] + h[0]x[n] + h[1]x[n-1] + \cdots$
 - ♦ Hafızasız: $y[n]$, sadece $x[n]$ 'ye bağlı olması
- $\forall n \neq 0$ iken $h[n] = 0$ olursa Hafızasız.

Sistem Özellikleri

- **Hafızalılık**
- $y[n] = \cdots + h[-1]x[n+1] + h[0]x[n] + h[1]x[n-1] + \cdots$
 - ♦ Hafızasız: $y[n]$, sadece $x[n]$ 'ye bağlı olması
- $\forall n \neq 0$ iken $h[n] = 0$ olursa Hafızasız.
 - ♦ $h[n] = A\delta[n]$

Sistem Özellikleri

- Hafızalılık

- $y[n] = \cdots + h[-1]x[n+1] + h[0]x[n] + h[1]x[n-1] + \cdots$

- ♦ Hafızasız: $y[n]$, sadece $x[n]$ 'ye bağlı olması

- $\forall n \neq 0$ iken $h[n] = 0$ olursa Hafızasız.

- ♦ $h[n] = A\delta[n]$

- $\exists n \neq 0$ iken $h[n] \neq 0$ olursa Hafızalı.

- ♦ $h[n] \neq A\delta[n]$

Örnek 4

- $h[n] = a^n u[n]$, Hafızalı mıdır?

Örnek 4

- $h[n] = a^n u[n]$, Hafızalı mıdır?
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Örnek 4

- $h[n] = a^n u[n]$, Hafızalı mıdır?
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Örnek 4

- $h[n] = a^n u[n]$, Hafızalı mıdır?
- $n \neq 0$ iken $h[n] \neq 0$
 - ♦ $n = 1$ iken $h[n] = a$
 - ♦ $n = 2$ iken $h[n] = a^2$
 - ♦ \vdots

Örnek 4

- $h[n] = a^n u[n]$, Hafızalı mıdır?
- $n \neq 0$ iken $h[n] \neq 0$
 - ♦ $n = 1$ iken $h[n] = a$
 - ♦ $n = 2$ iken $h[n] = a^2$
 - ♦ \vdots
- Hafızalı

Örnek 5

- $h[n] = \delta[n - n_0]$, Hafızalı mıdır?

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Örnek 5

- $h[n] = \delta[n - n_0]$, Hafızalı mıdır?
- $n \neq 0$ iken $h[n]$
- $h[n] = \delta[n - n_0] = \begin{cases} 0, & n \neq n_0 \\ 1, & n = n_0 \end{cases}$
 - ♦ $n_0 = 0$ ise

Örnek 5

- $h[n] = \delta[n - n_0]$, Hafızalı mıdır?
- $n \neq 0$ iken $h[n]$
- $h[n] = \delta[n - n_0] = \begin{cases} 0, & n \neq n_0 \\ 1, & n = n_0 \end{cases}$
 - ♦ $n_0 = 0$ ise Hafızasız
 - ♦ $n_0 \neq 0$ ise

Örnek 5

- $h[n] = \delta[n - n_0]$, Hafızalı mıdır?
- $n \neq 0$ iken $h[n]$
- $h[n] = \delta[n - n_0] = \begin{cases} 0, & n \neq n_0 \\ 1, & n = n_0 \end{cases}$
 - ♦ $n_0 = 0$ ise Hafızasız
 - ♦ $n_0 \neq 0$ ise Hafızalı

Örnek 6

- $h[n] = u[n]$, Hafızalı mıdır?

Örnek 6

- $h[n] = u[n]$, Hafızalı mıdır?
- $n \neq 0$ iken $h[n] = ?$

Örnek 6

- $h[n] = u[n]$, Hafızalı mıdır?
- $n \neq 0$ iken $h[n] \neq 0$

Örnek 6

- $h[n] = u[n]$, Hafızalı mıdır?
- $n \neq 0$ iken $h[n] \neq 0$
 - ♦ $n = 1$ iken $h[n] = 1$
 - ♦ $n = 2$ iken $h[n] = 1$
 - ♦ \vdots

Örnek 6

- $h[n] = u[n]$, Hafızalı mıdır?
- $n \neq 0$ iken $h[n] \neq 0$
 - ♦ $n = 1$ iken $h[n] = 1$
 - ♦ $n = 2$ iken $h[n] = 1$
 - ♦ \vdots
- Hafızalı

- Nedensellik
- $y[n] = \cdots + h[-1]x[n+1] + h[0]x[n] + h[1]x[n-1] + \cdots$
 - ♦ Nedensel: $y[n]$, sadece

- Nedensellik

- $y[n] = \cdots + h[-1]x[n+1] + h[0]x[n] + h[1]x[n-1] + \cdots$

- ♦ Nedensel: $y[n]$, sadece $x[n]$ ve/veya $x[n-k]$ 'ya bağlı olması

- $y[n] = \underbrace{\cdots + h[-1]x[n+1] + h[0]x[n] + h[1]x[n-1] + \cdots}_0$

- $\forall n < 0$ iken $h[n] = 0$ ise Nedensel.

- **Nedensellik**

- $y[n] = \cdots + h[-1]x[n+1] + h[0]x[n] + h[1]x[n-1] + \cdots$

- ♦ Nedensel: $y[n]$, sadece $x[n]$ ve/veya $x[n-k]$ 'ya bağlı olması

- $y[n] = \underbrace{\cdots + h[-1]x[n+1] + h[0]x[n] + h[1]x[n-1] + \cdots}_0$

- $\forall n < 0$ iken $h[n] = 0$ ise Nedensel.

- $\exists n < 0$ iken $h[n] \neq 0$ ise Nedensel değil.

Örnek 7

- $h[n] = a^n u[n]$, Nedensel midir?
 - ♦ Hafızalı

Örnek 7

- $h[n] = a^n u[n]$, Nedensel midir?
 - ♦ Hafızalı
- $n < 0$ iken $h[n] = ?$

Örnek 7

- $h[n] = a^n u[n]$, Nedensel midir?
 - ♦ Hafızalı
- $n < 0$ iken $h[n] = 0$

Örnek 7

- $h[n] = a^n u[n]$, Nedensel midir?
 - ♦ Hafızalı
- $n < 0$ iken $h[n] = 0$
 - ♦ $n < 0$ iken $u[n] = 0$

Örnek 7

- $h[n] = a^n u[n]$, Nedensel midir?
 - ♦ Hafızalı
- $n < 0$ iken $h[n] = 0$
 - ♦ $n < 0$ iken $u[n] = 0$
- Nedensel

Örnek 8

- $h[n] = \delta[n - n_0]$, Nedensel midir?
 - ♦ Hafızalı

Örnek 8

- $h[n] = \delta[n - n_0]$, Nedensel midir?
 - ♦ Hafızalı
- $n < 0$ iken $h[n] = ?$

Örnek 8

- $h[n] = \delta[n - n_0]$, Nedensel midir?
 - ♦ Hafızalı
- $n < 0$ iken $h[n] = ?$
- $$\delta[n - n_0] = \begin{cases} 0, & n \neq n_0 \\ 1, & n = n_0 \end{cases}$$

Örnek 8

- $h[n] = \delta[n - n_0]$, Nedensel midir?
 - ♦ Hafızalı
- $n < 0$ iken $h[n] = ?$
- $\delta[n - n_0] = \begin{cases} 0, & n \neq n_0 \\ 1, & n = n_0 \end{cases}$
- $n = n_0 < 0$ iken $h[n] = 1$
 - ♦ Nedensel değil.

Örnek 8

- $h[n] = \delta[n - n_0]$, Nedensel midir?
 - ♦ Hafızalı
- $n < 0$ iken $h[n] = ?$
- $\delta[n - n_0] = \begin{cases} 0, & n \neq n_0 \\ 1, & n = n_0 \end{cases}$
- $n = n_0 < 0$ iken $h[n] = 1$
 - ♦ Nedensel değil.
- $n = n_0 \geq 0$ iken $h[n] = 1$
- $n < 0$ iken $h[n] = 0$
 - ♦ Nedensel.

Örnek 9

- $h[n] = u[n]$, Nedensel midir?
 - ♦ Hafızalı

Örnek 9

- $h[n] = u[n]$, Nedensel midir?
 - ♦ Hafızalı
- $n < 0$ iken $h[n] = ?$

Örnek 9

- $h[n] = u[n]$, Nedensel midir?
 - ♦ Hafızalı
- $n < 0$ iken $h[n] = 0$

Örnek 9

- $h[n] = u[n]$, Nedensel midir?
 - ♦ Hafızalı
- $n < 0$ iken $h[n] = 0$
 - ♦ $n < 0$ iken $u[n] = 0$

Örnek 9

- $h[n] = u[n]$, Nedensel midir?
 - ♦ Hafızalı
- $n < 0$ iken $h[n] = 0$
 - ♦ $n < 0$ iken $u[n] = 0$
- Nedensel

Sistem Özellikleri

- Kararlılık
- $\sum_{n=-\infty}^{\infty} |h[n]| < \infty$ ise Kararlı.

- **Kararlılık**
- $\sum_{n=-\infty}^{\infty} |h[n]| < \infty$ ise Kararlı.
- $\sum_{n=-\infty}^{\infty} |h[n]| \rightarrow \infty$ ise Kararsız.

Örnek 10

- $h[n] = a^n u[n]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel

Örnek 10

- $h[n] = a^n u[n]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel
- $\sum_{n=-\infty}^{\infty} |h[n]| = ?$

Örnek 10

- $h[n] = a^n u[n]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel
- $\sum_{n=-\infty}^{\infty} |h[n]| = ?$
- $\sum_{n=-\infty}^{\infty} a^n u[n] = ?$

Örnek 10

- $h[n] = a^n u[n]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel
- $\sum_{n=-\infty}^{\infty} |h[n]| = ?$
- $\sum_{n=0}^{\infty} a^n = \begin{cases} \infty, & a \geq 1 \end{cases}$

Örnek 10

- $h[n] = a^n u[n]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel
- $\sum_{n=-\infty}^{\infty} |h[n]| = ?$
- $\sum_{n=0}^{\infty} a^n = \begin{cases} \infty, & a \geq 1 \\ \frac{1}{1-a}, & a < 1 \end{cases}$

Örnek 10

- $h[n] = a^n u[n]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel
- $\sum_{n=-\infty}^{\infty} |h[n]| = ?$
- $\sum_{n=0}^{\infty} a^n = \begin{cases} \infty, & a \geq 1 \\ \frac{1}{1-a}, & a < 1 \end{cases}$
- $a \geq 1$ iken Kararsız

Örnek 10

- $h[n] = a^n u[n]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel
- $\sum_{n=-\infty}^{\infty} |h[n]| = ?$
- $\sum_{n=0}^{\infty} a^n = \begin{cases} \infty, & a \geq 1 \\ \frac{1}{1-a}, & a < 1 \end{cases}$
- $a \geq 1$ iken Kararsız
- $a < 1$ iken Kararlı

Örnek 11

- $h[n] = \delta[n - n_0]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel

Örnek 11

- $h[n] = \delta[n - n_0]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel
- $\sum_{n=-\infty}^{\infty} |h[n]| = ?$

Örnek 11

- $h[n] = \delta[n - n_0]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel
- $\sum_{n=-\infty}^{\infty} |h[n]| = ?$
- $\sum_{n=-\infty}^{\infty} \delta[n - n_0] =$

Örnek 11

- $h[n] = \delta[n - n_0]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel
- $\sum_{n=-\infty}^{\infty} |h[n]| = ?$
- $\sum_{n=-\infty}^{\infty} \delta[n - n_0] = 1$

Örnek 11

- $h[n] = \delta[n - n_0]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel
- $\sum_{n=-\infty}^{\infty} |h[n]| = ?$
- $\sum_{n=-\infty}^{\infty} \delta[n - n_0] = 1 < \infty$
- Kararlı

Örnek 12

- $h[n] = u[n]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel

Örnek 12

- $h[n] = u[n]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel
- $\sum_{n=-\infty}^{\infty} |h[n]| = ?$

Örnek 12

- $h[n] = u[n]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel
- $\sum_{n=-\infty}^{\infty} |h[n]| = ?$
- $\sum_{n=-\infty}^{\infty} u[n] =$

Örnek 12

- $h[n] = u[n]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel
- $\sum_{n=-\infty}^{\infty} |h[n]| = ?$
- $\sum_{n=-\infty}^{\infty} u[n] = \sum_{n=0}^{\infty} 1$

Örnek 12

- $h[n] = u[n]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel
- $\sum_{n=-\infty}^{\infty} |h[n]| = ?$
- $\sum_{n=-\infty}^{\infty} u[n] = \sum_{n=0}^{\infty} 1 = \infty$

Örnek 12

- $h[n] = u[n]$, Kararlı mıdır?
 - ♦ Hafızalı
 - ♦ Nedensel
- $\sum_{n=-\infty}^{\infty} |h[n]| = ?$
- $\sum_{n=-\infty}^{\infty} u[n] = \sum_{n=0}^{\infty} 1 = \infty$
- Kararsız