



Universidade Federal de Campina Grande
Departamento de Engenharia Elétrica

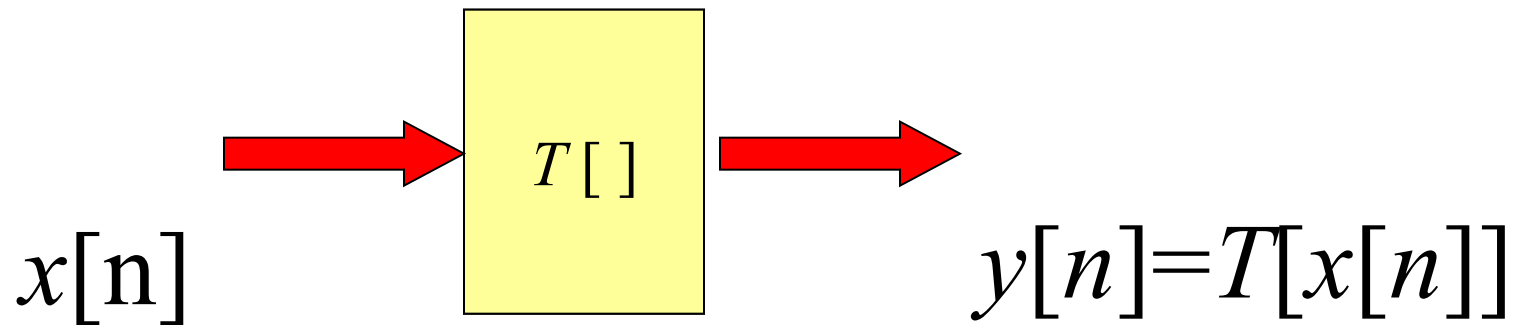
Análise de Sinais e Sistemas

Aula: Sistemas lineares invariantes no tempo

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SISTEMAS DISCRETOS NO TEMPO LTI (LINEAR INVARIANTE NO TEMPO)



$$x[n] = \sum_{k=-\infty}^{\infty} x[k] \delta[n-k]$$

SISTEMAS DISCRETOS NO TEMPO LTI (LINEAR INVARIANTE NO TEMPO)

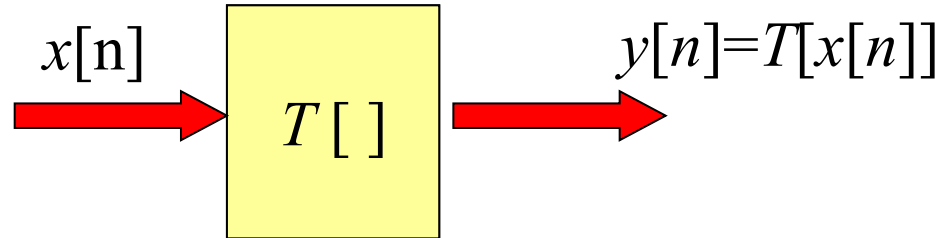
- Definindo

$$h[n] = T[\delta[n]]$$

Como a **resposta do sistema ao impulso**
E considerando o sistema como linear e
invariante no tempo, tem-se:

$$h[n - k] = T[\delta[n - k]]$$

SISTEMAS DISCRETOS NO TEMPO LTI (LINEAR INVARIANTE NO TEMPO)



$$x[n] = \sum_{k=-\infty}^{\infty} x[k] \delta[n-k]$$

$$y[n] = T[x[n]]$$

$$y[n] = T\left[\sum_{k=-\infty}^{\infty} x[k] \delta[n-k]\right]$$

$$y[n] = \sum_{k=-\infty}^{\infty} x[k] \cdot T[\delta[n-k]]$$

$$y[n] = \sum_{k=-\infty}^{\infty} x[k] \cdot h[n-k]$$

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

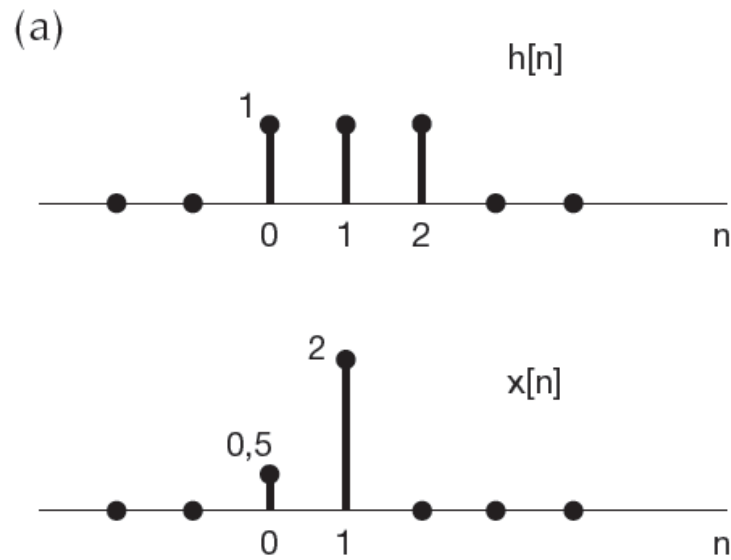
CONVOLUÇÃO DISCRETA

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

$$y[n] = \sum_{k=-\infty}^{\infty} x[k].h[n-k]$$

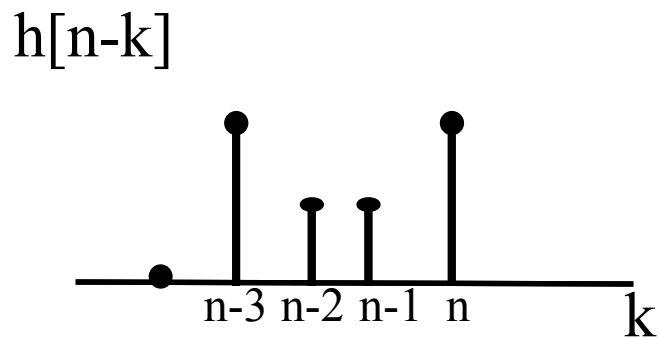
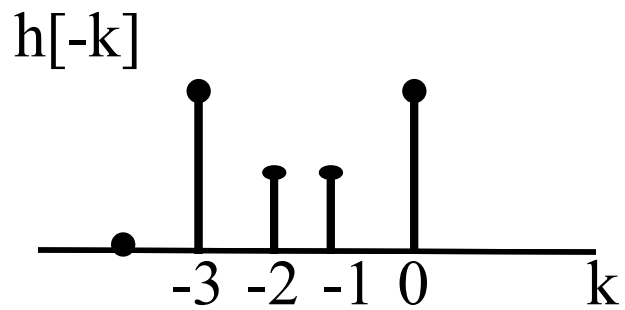
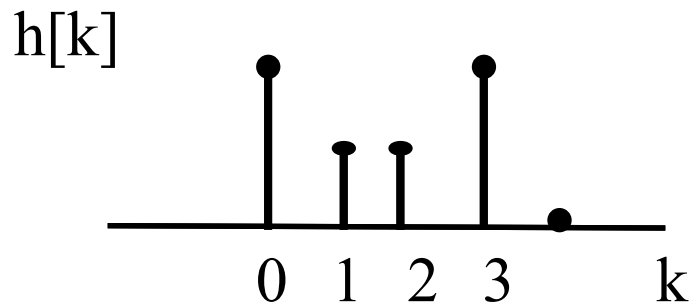
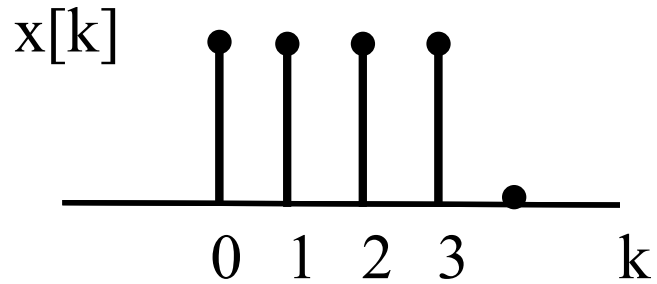
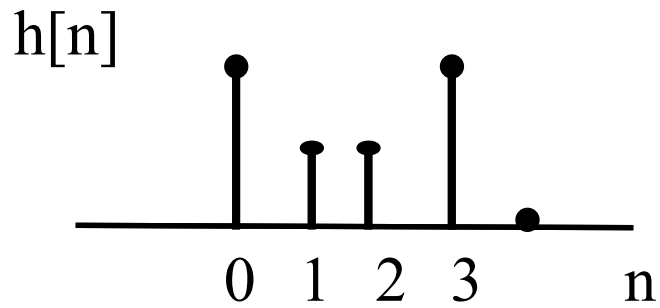
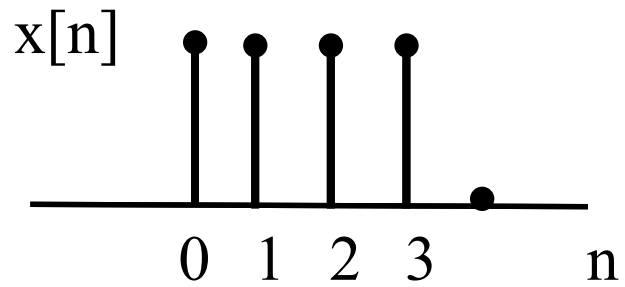
- Qualquer sistema LTI é completamente caracterizado pela resposta ao impulso do sistema

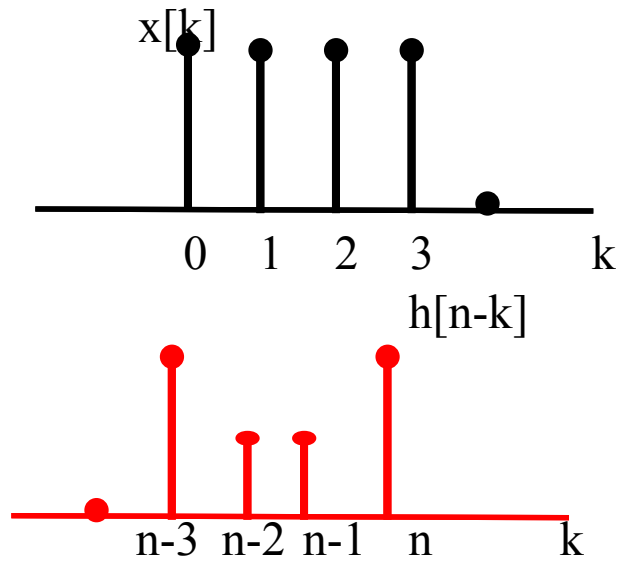
EXEMPLO



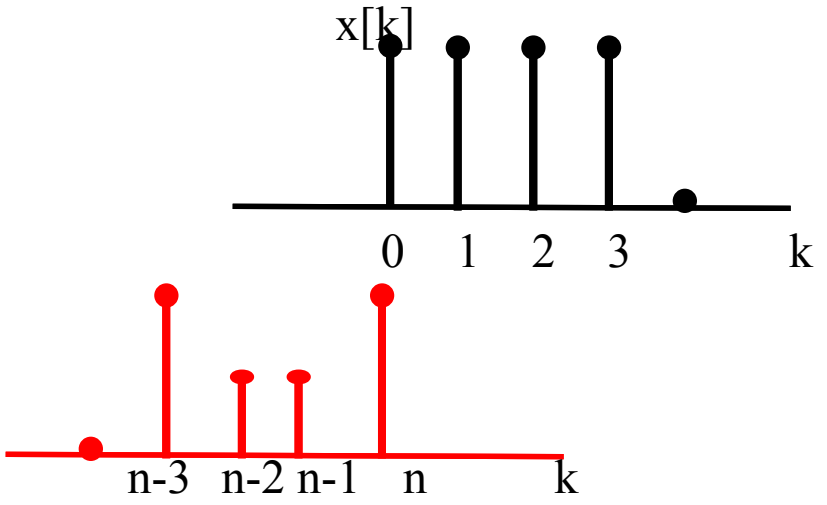
$$y[n] = ???$$

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

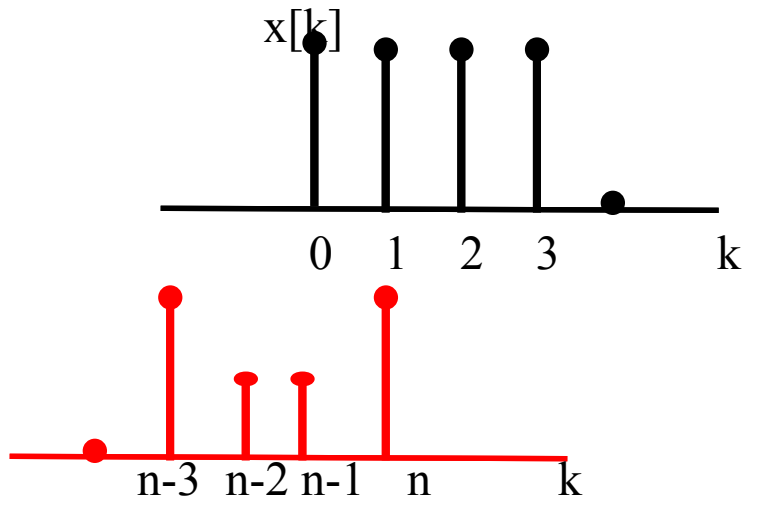




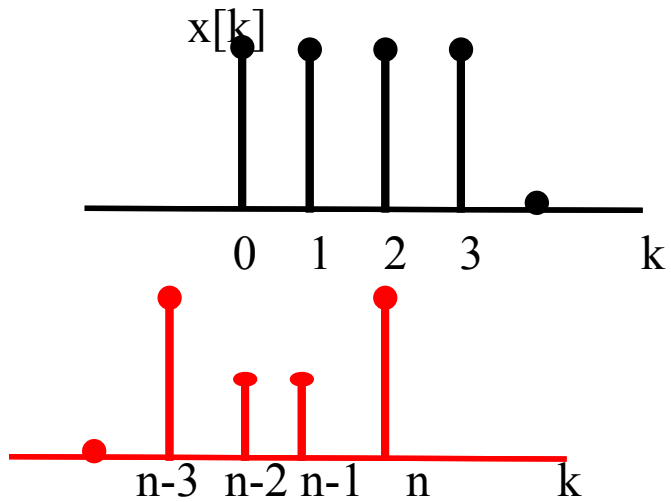
Para $n=0$



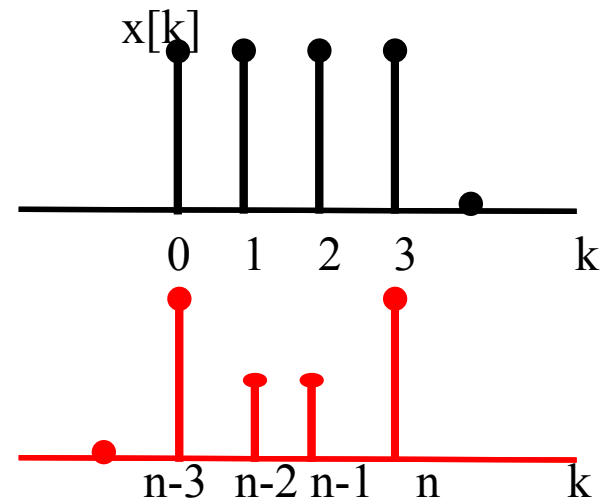
Para $n=1$



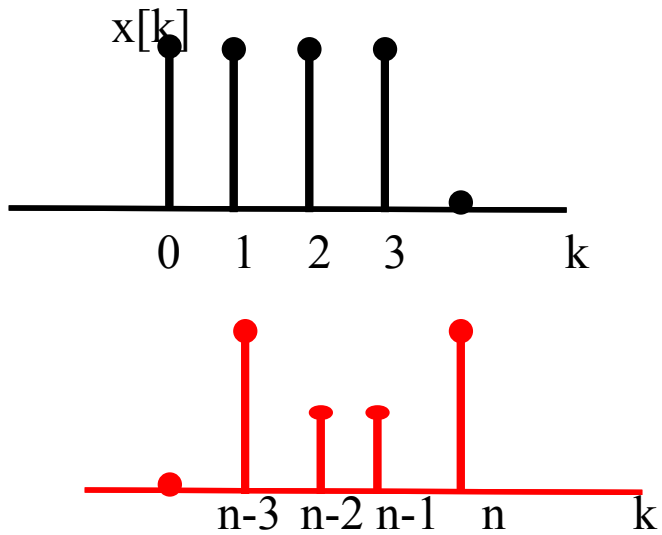
Para $n=2$



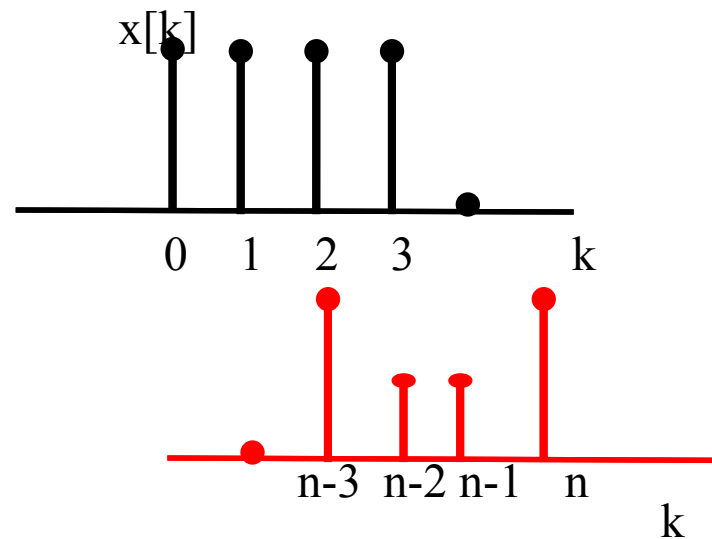
Para $n=3$



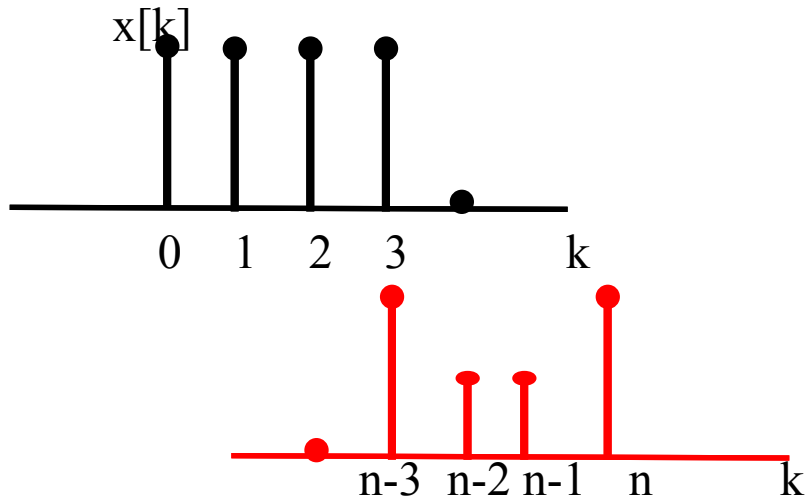
Para $n=4$



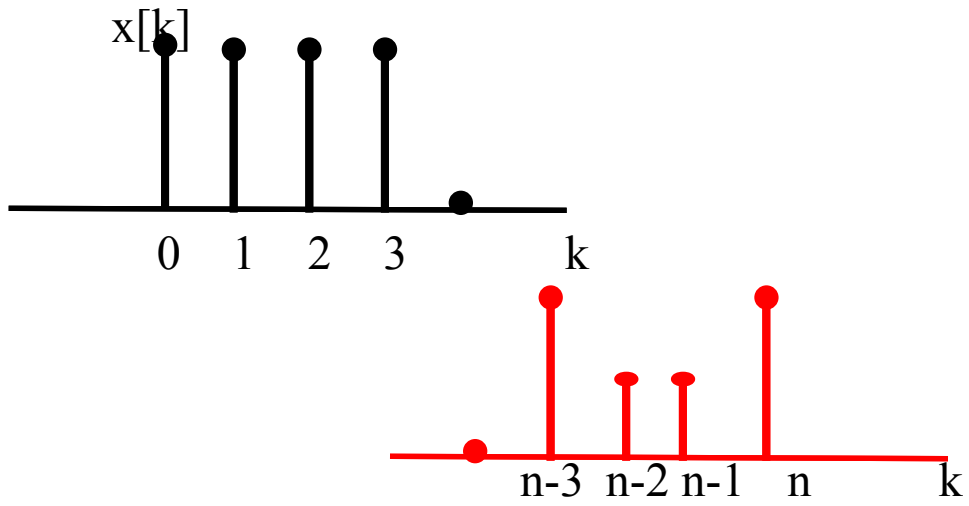
Para $n=5$



Para $n=6$



Para $n > 7$



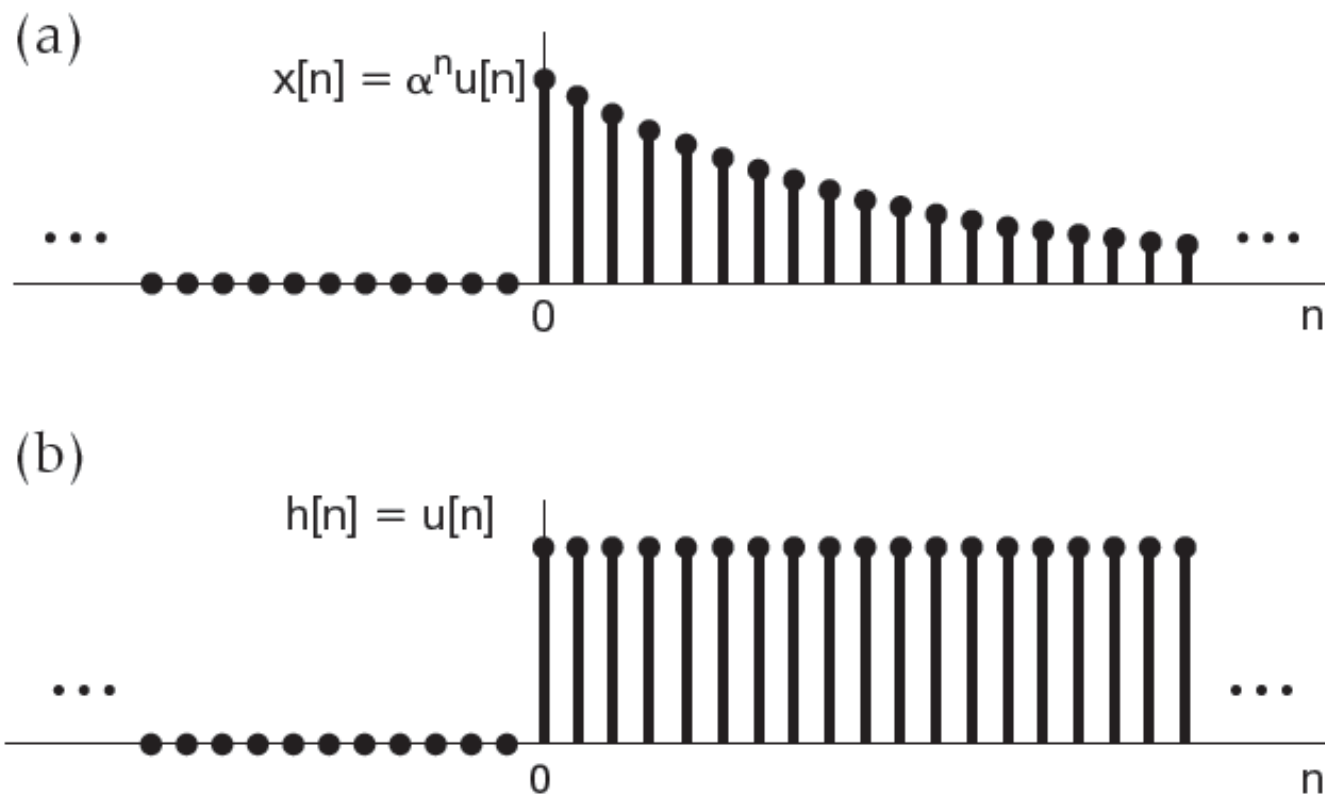
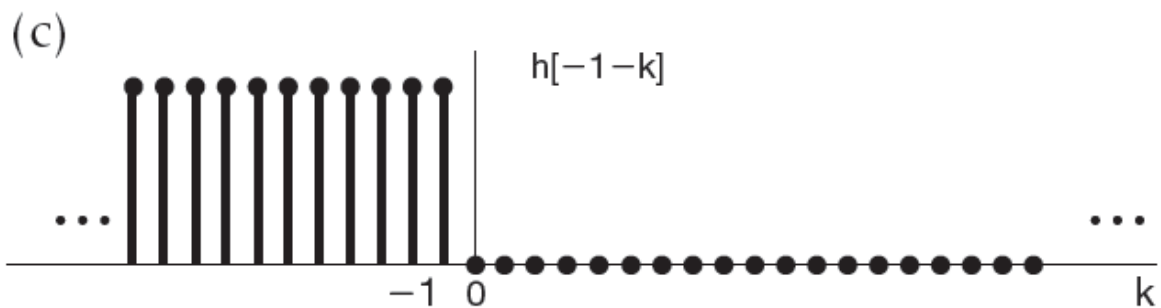
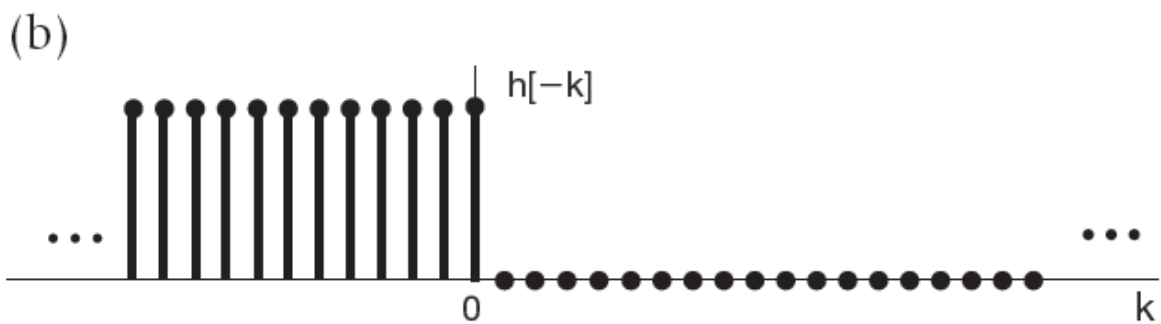
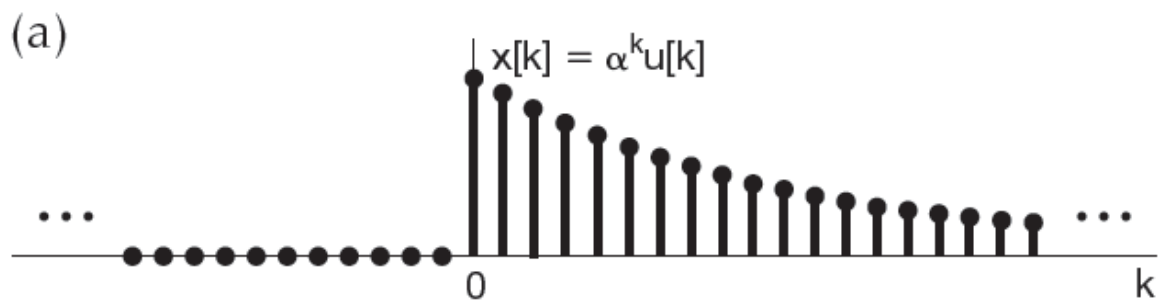


Figura 2.5 Sinais $x[n]$ e $h[n]$ no Exemplo 2.3.



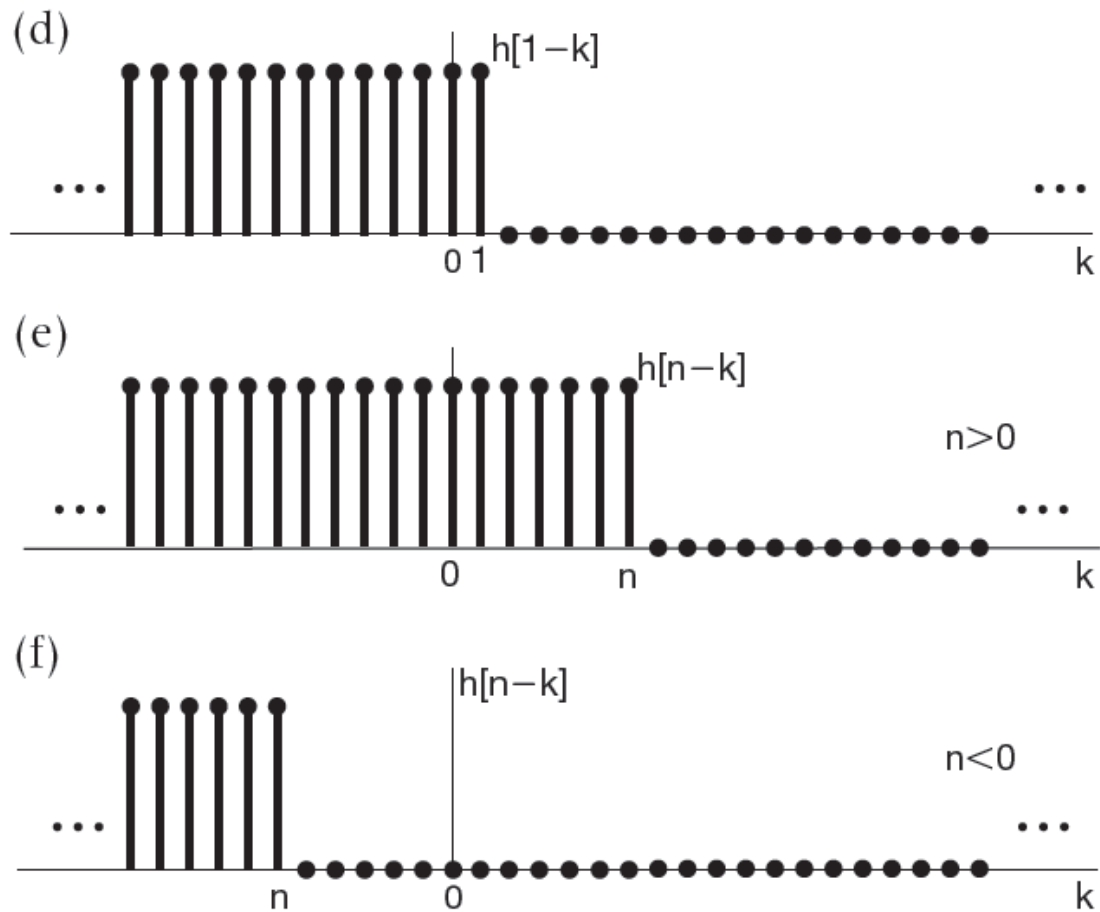
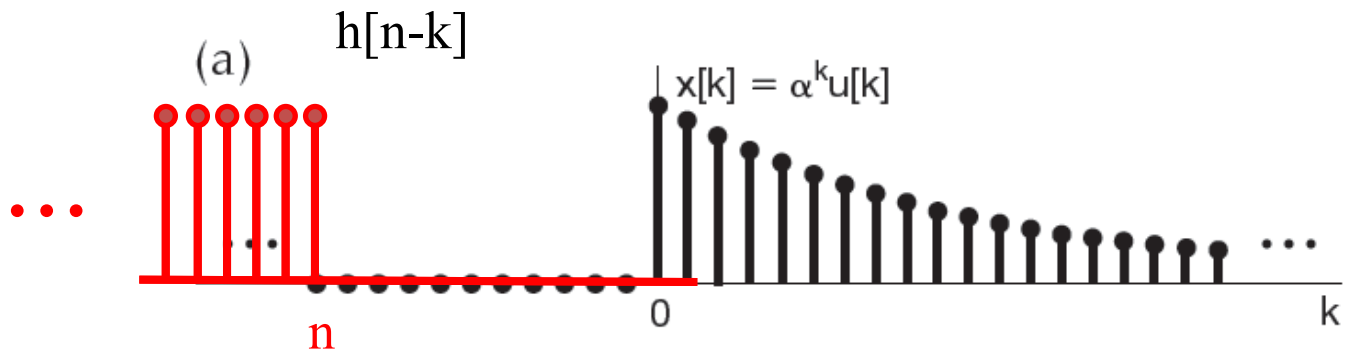
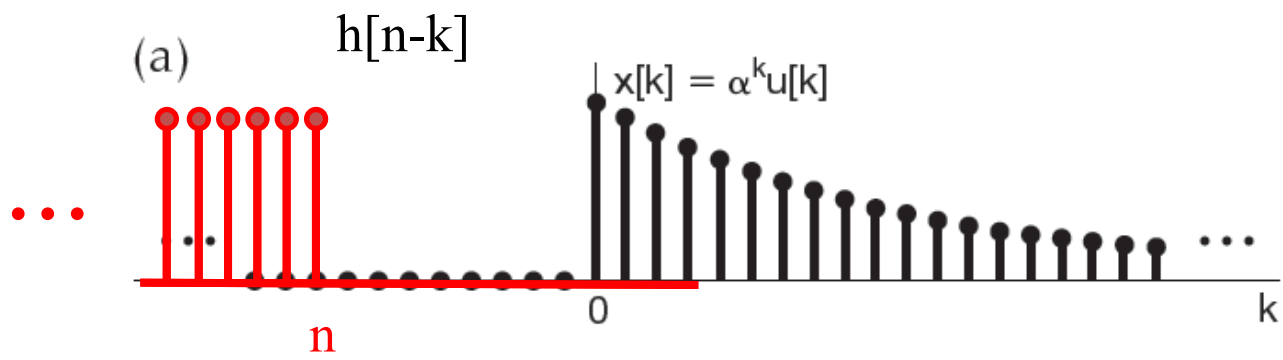
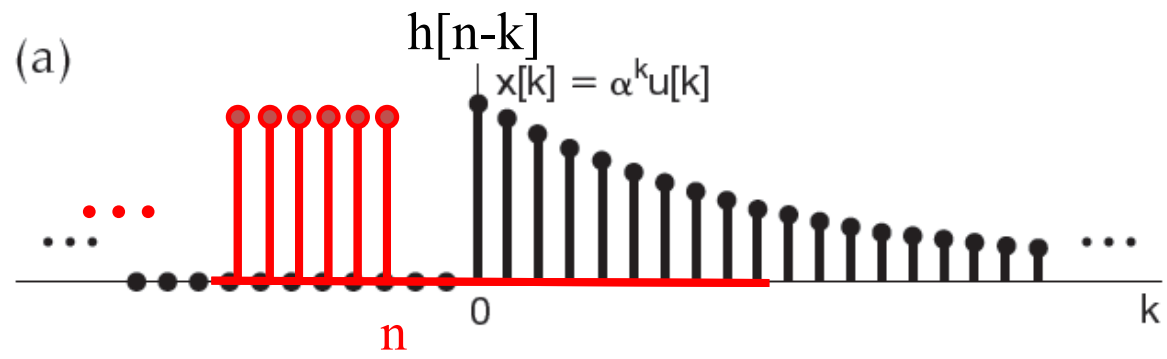
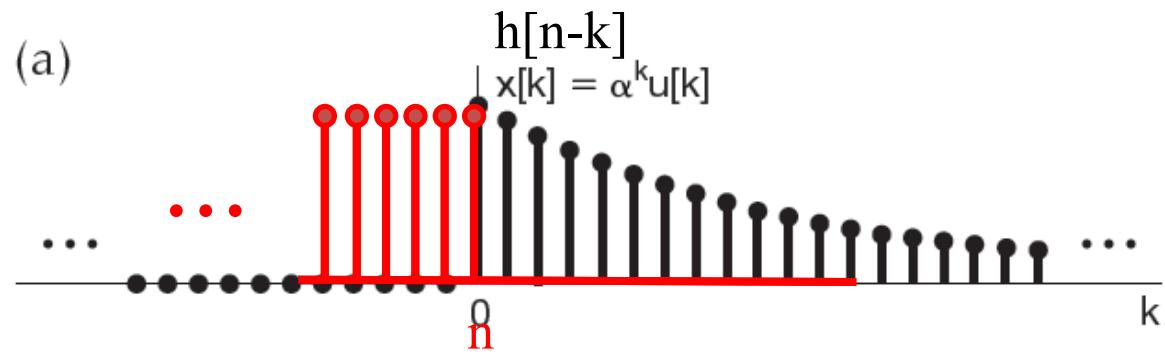


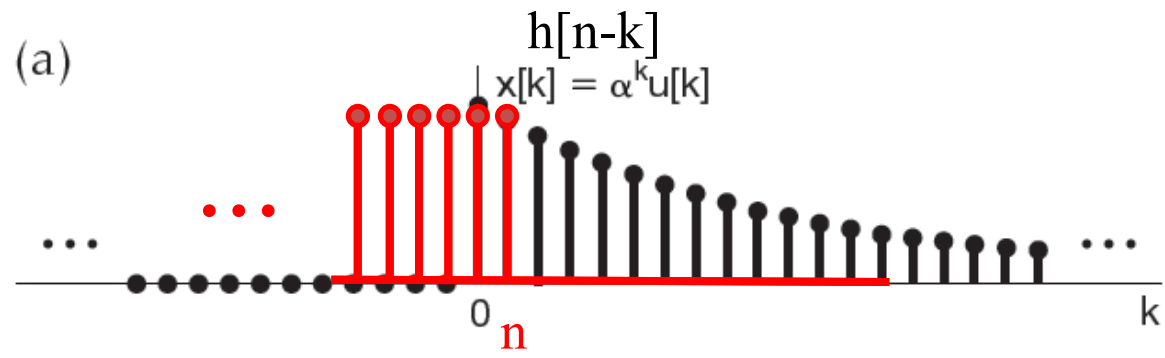
Figura 2.6 Interpretação gráfica do cálculo da soma de convolução para o Exemplo 2.3. ■

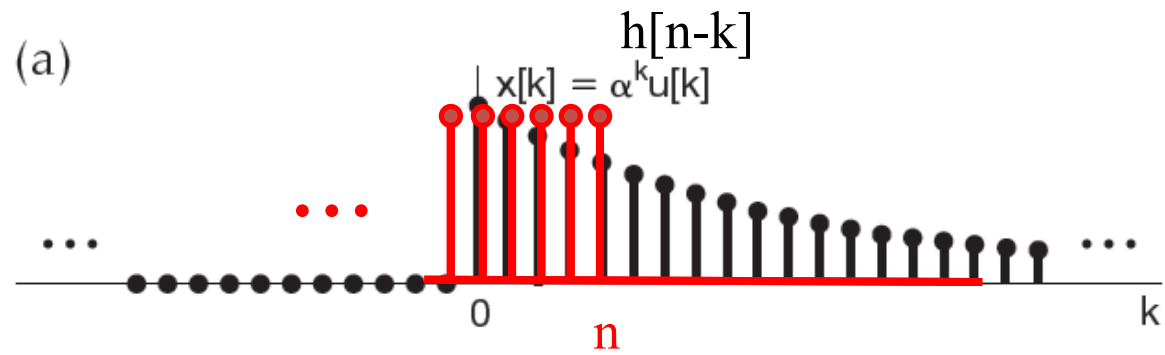


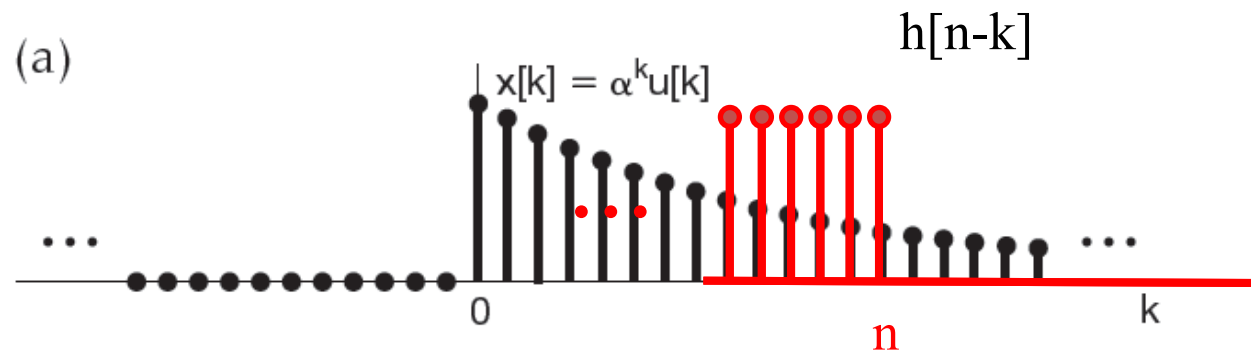












PROPRIEDADES DA CONVOLUÇÃO DISCRETA

1. Propriedade comutativa

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

2. Propriedade distributiva

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

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

PROPRIEDADES DA CONVOLUÇÃO DISCRETA

3. Propriedade associativa

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

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

PROPRIEDADES DOS SISTEMAS LTI

- Sistema sem memória

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

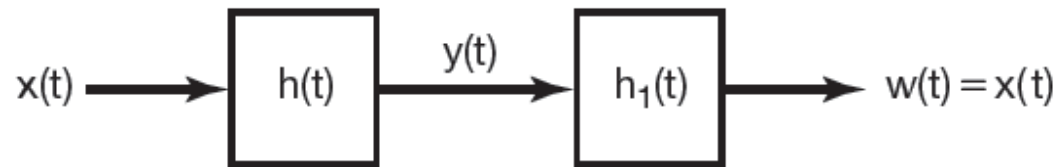
$$y[n] = \sum_{k=-\infty}^{\infty} x[k]h[n-k] = \sum_{k=-\infty}^{\infty} x[n-k]h[k]$$

$$h[k] = 0, k \neq 0$$

$$h[n] = k\delta[n]$$

PROPRIEDADES DOS SISTEMAS LTI

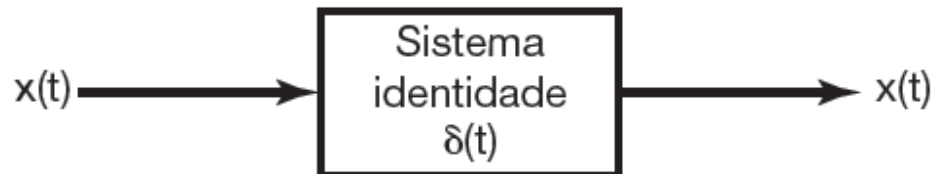
- Sistema inversível



$$w[n] = x[n]$$

$$w[n] = x[n] * [h_1[n] * h_2[n]]$$

$$h_1[n] * h_2[n] = \delta[n]$$



PROPRIEDADES DOS SISTEMAS LTI

- Sistema causal

$$y[n] = \sum_{k=-\infty}^{\infty} h[k]x[n-k]$$

$$h[n] = 0, n < 0$$

PROPRIEDADES DOS SISTEMAS

LTI

- Sistema estável

$$|y[n]| = \left| \sum_{k=-\infty}^{\infty} x[k]h[n-k] \right| = \left| \sum_{k=-\infty}^{\infty} x[n-k]h[k] \right|$$

$$|y[n]| \leq \sum_{k=-\infty}^{\infty} |x[n-k]| |h[k]|$$

$$|y[n]| \leq B \sum_{k=-\infty}^{\infty} |h[k]|$$

$$\sum_{k=-\infty}^{\infty} |h[k]| < \infty$$

O sistema é estável se e somente se sua resposta ao impulso for absolutamente somável