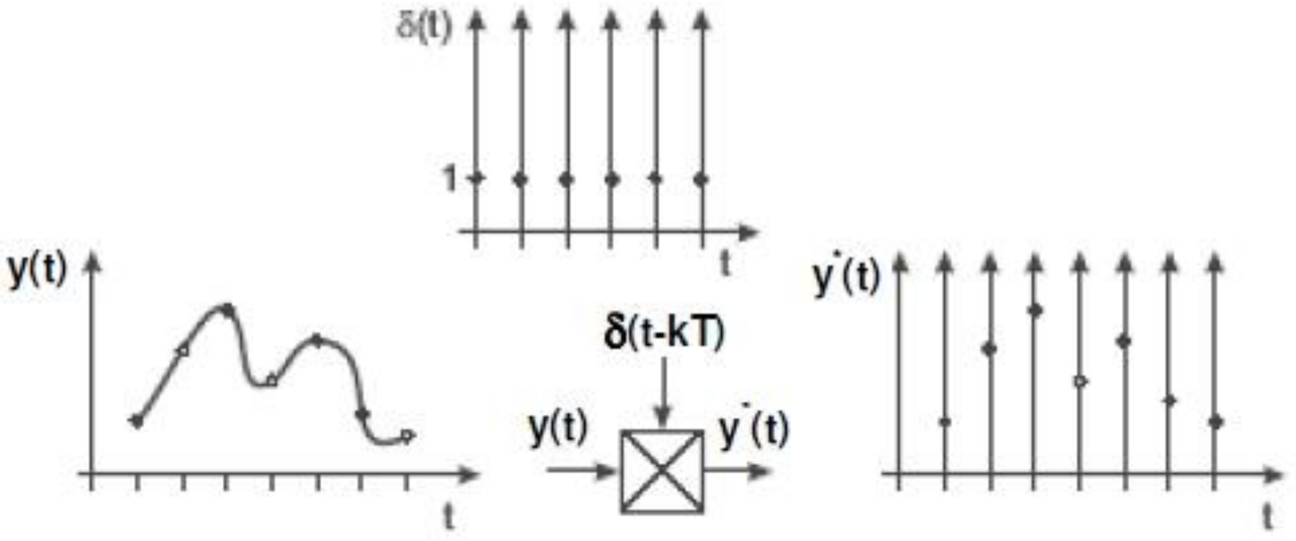
CUDAR
CENTRO UNIVERSITARIO DE AUTOMACIÓN Y ROBÓTICA

UTN
Facultad Regional Córdoba

TECNICAS DIGITALES III

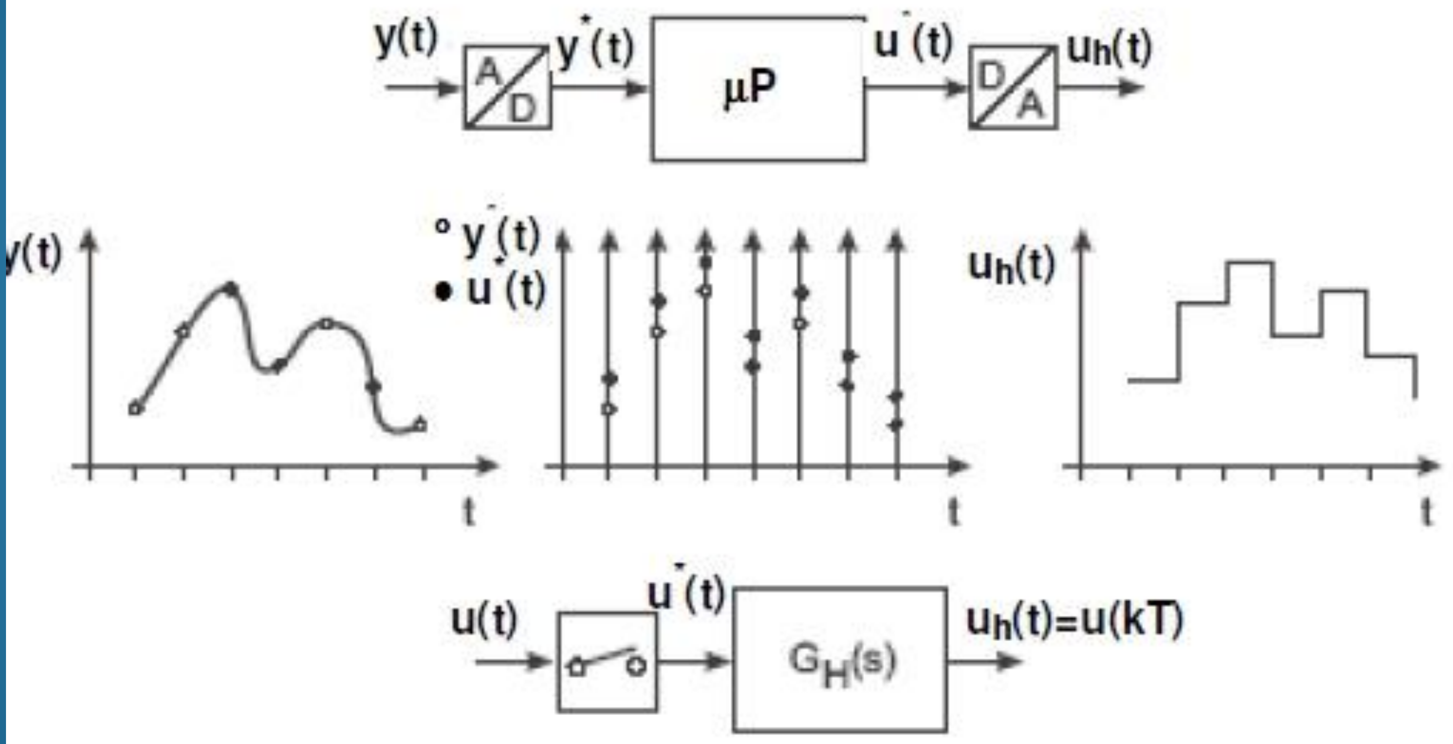
Conversor AD

$$y(t)\cdot\sum_{k=-\infty}^{\infty}\delta(t-kT)=y^{*}(t)$$



Modelo gráfico de un convertidor A/D.

Conversor AD



Modelo gráfico de un convertidor D/A.

Conversor AD

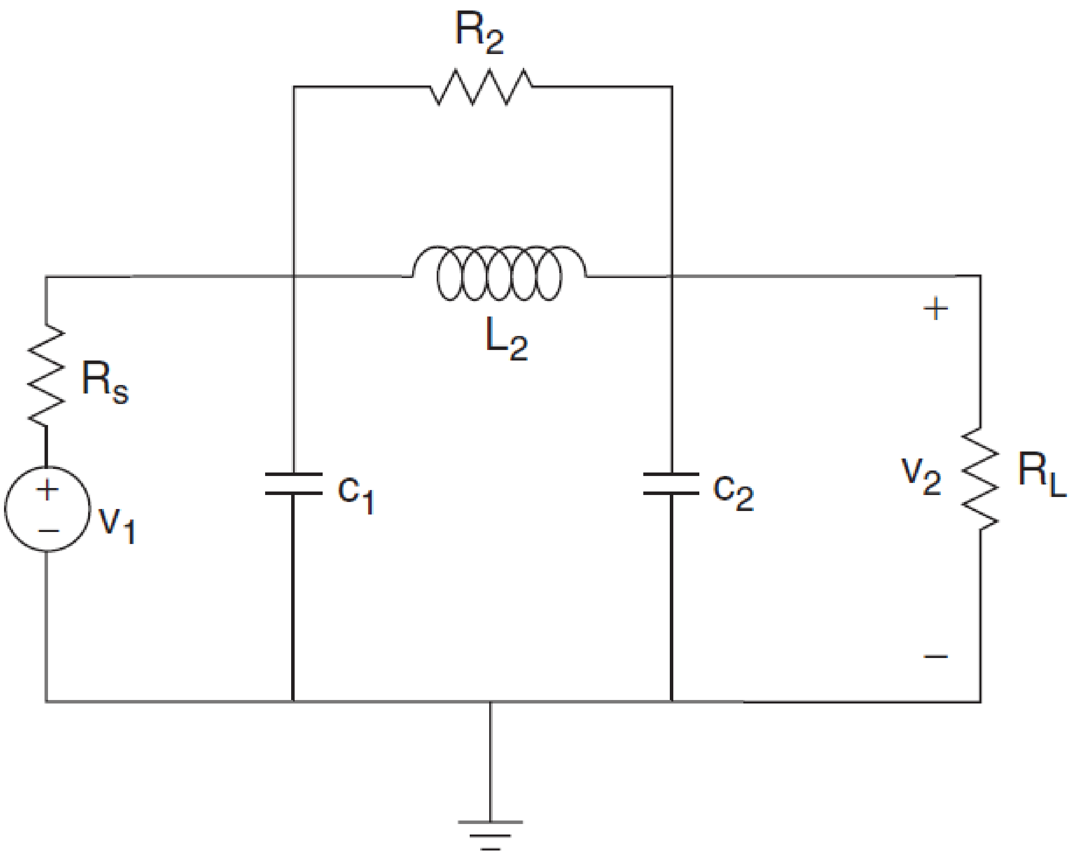


Figure 1.12 A lowpass analog *LC* filter.

Conversor AD

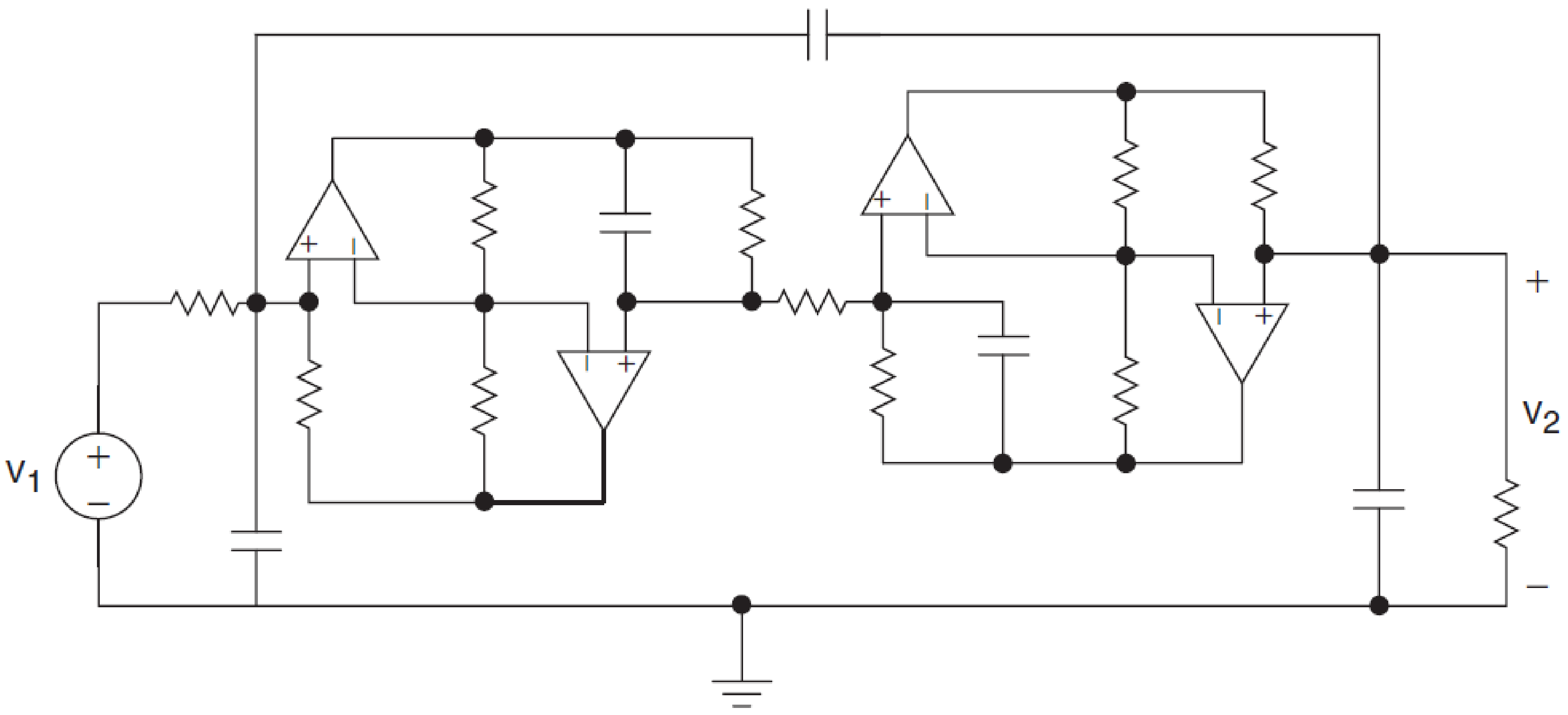


Figure 1.13 An active-*RC* lowpass analog filter.

Conversor AD

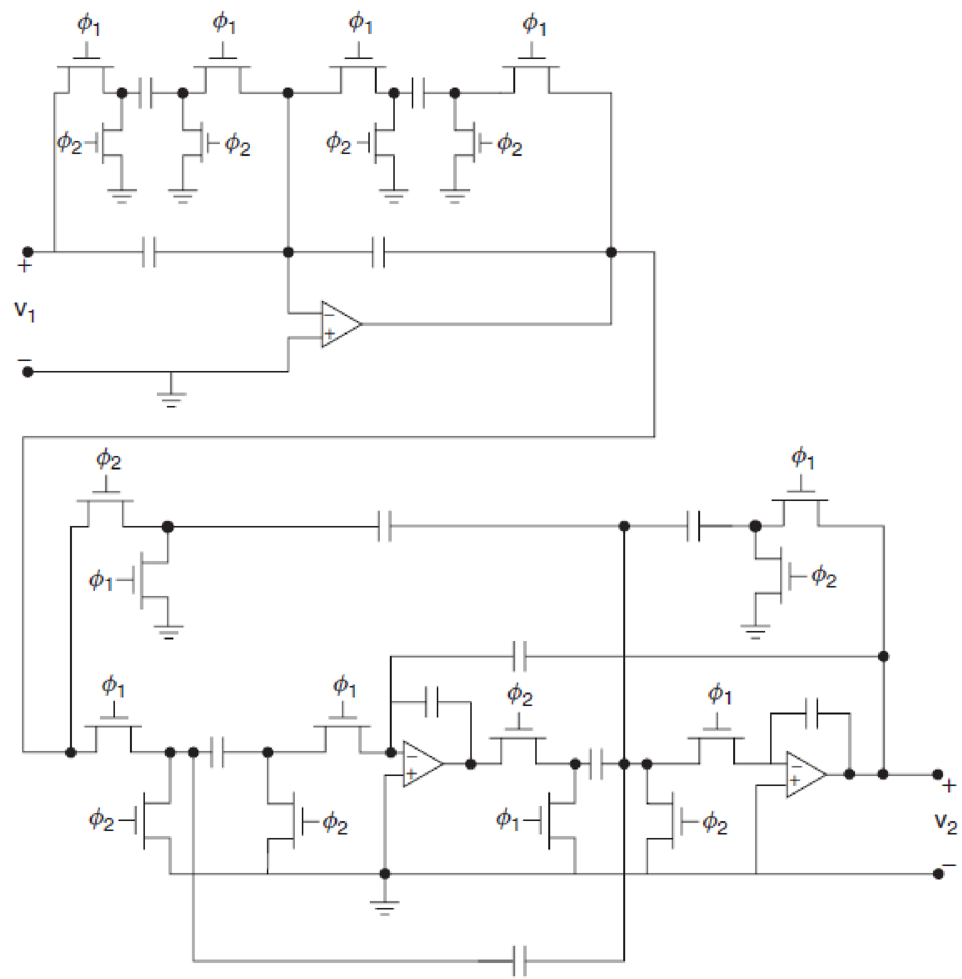


Figure 1.14 A switched-capacitor lowpass (analog) filter.

Conversor AD

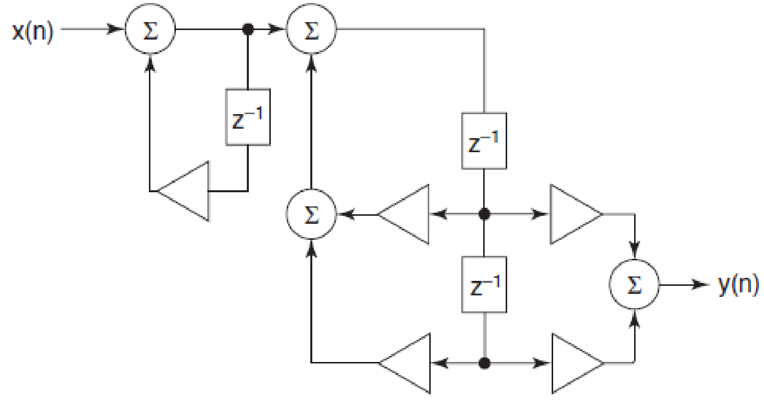


Figure 1.15 A lowpass third-order digital filter.

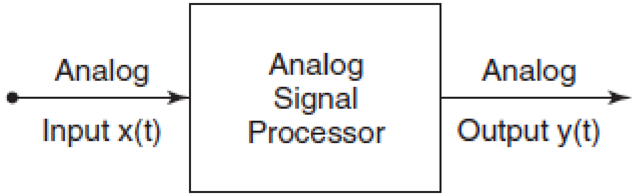


Figure 1.16 Example of an analog signal processing system.

Conversor AD

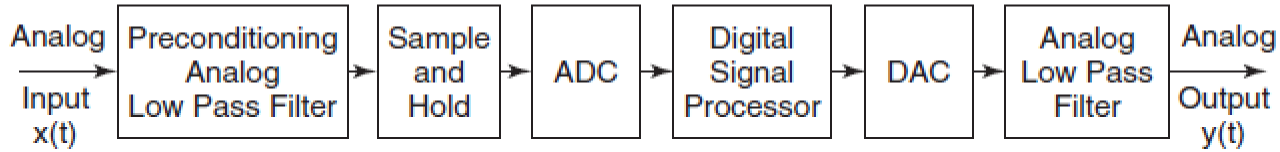


Figure 1.17 Example of a digital signal processing system.

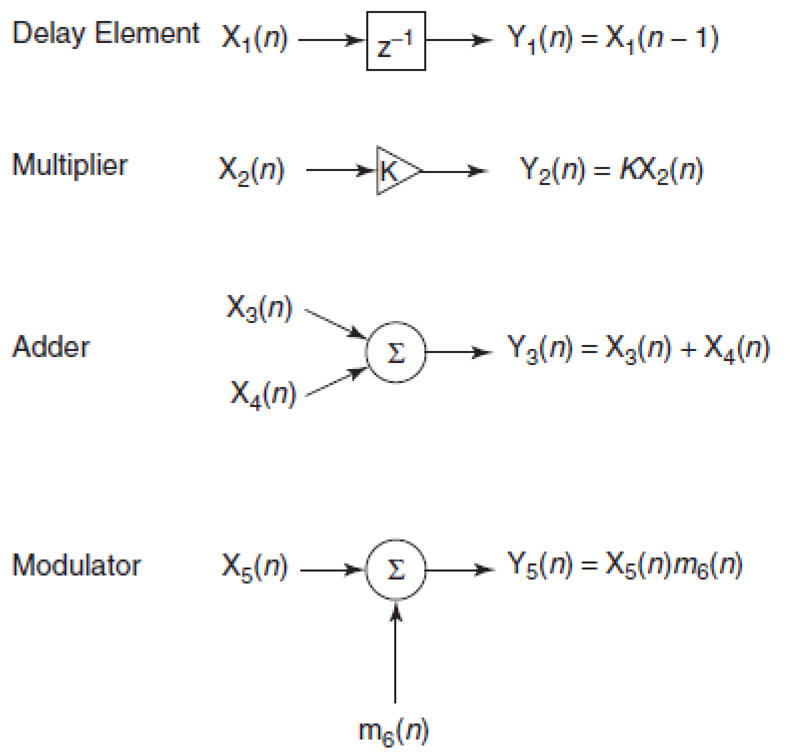


Figure 2.1 The basic components used in a discrete-time system.

Conversor AD

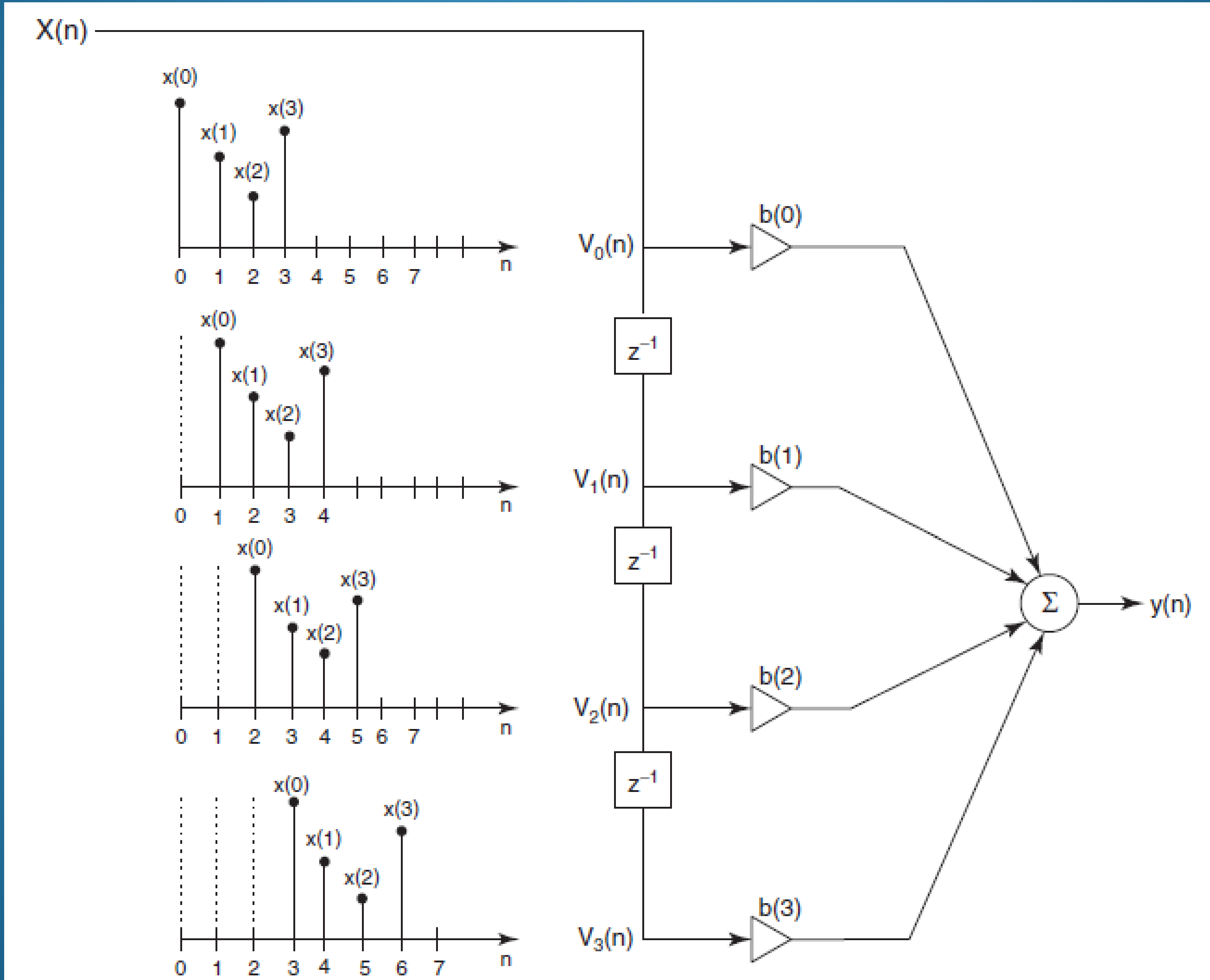


Figure 2.2 Operations in a typical discrete-time system.

Conversor AD

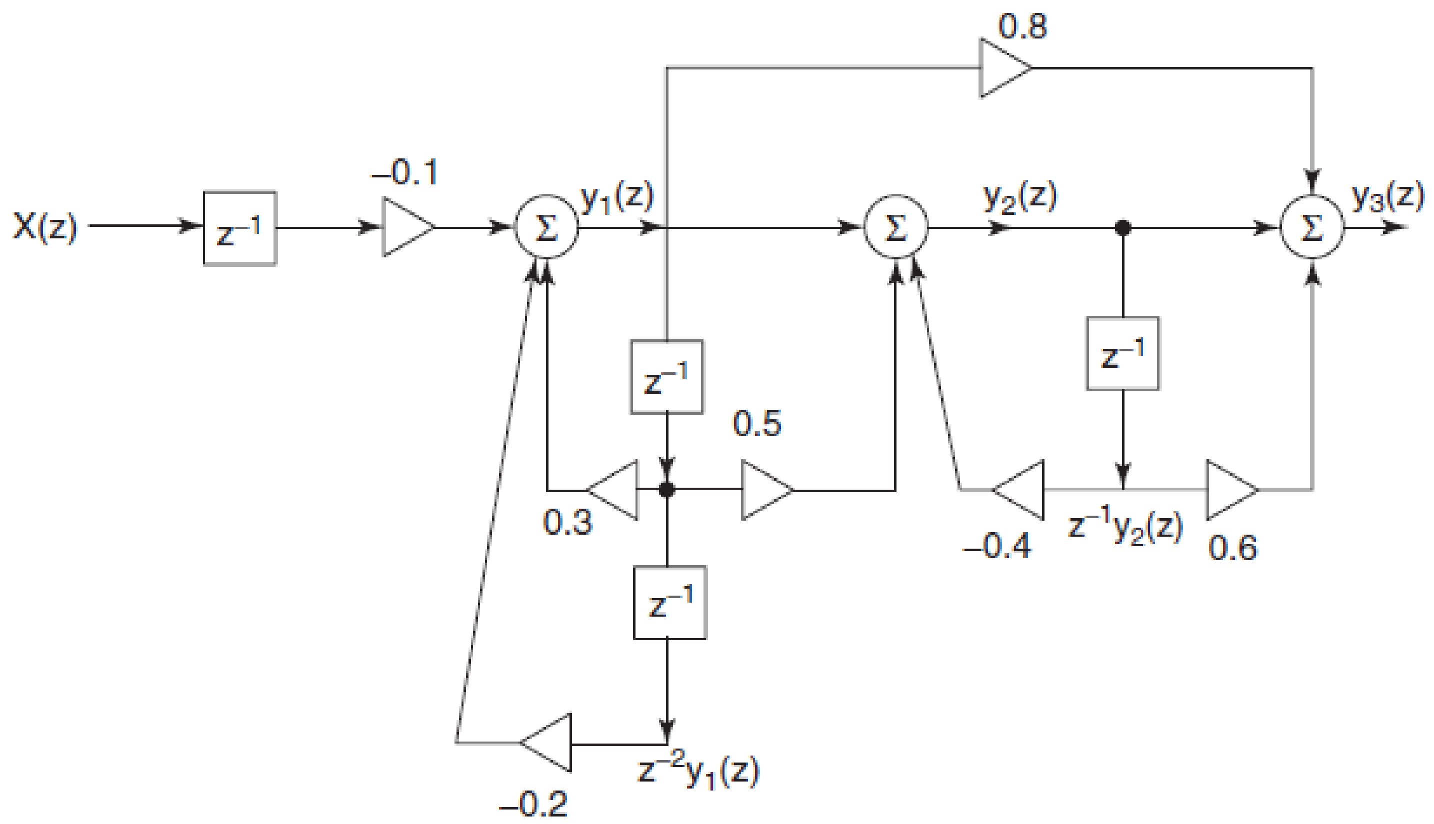
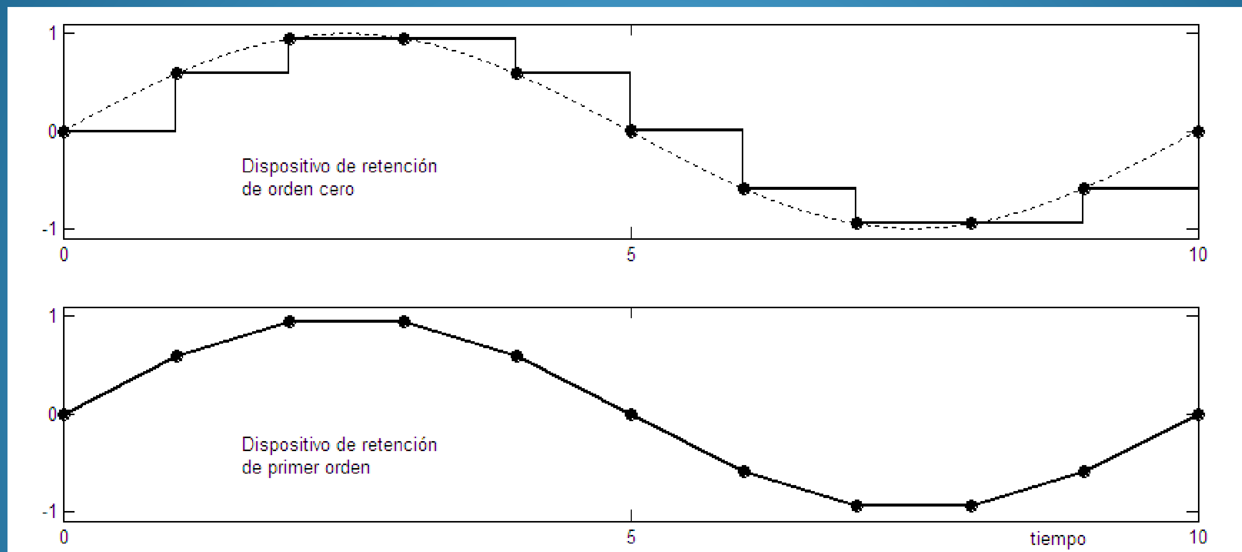


Figure 2.3 Schematic circuit for a discrete-time system.

Retenedor de orden ‘0’ ‘zoh’



$$kT \leq \tau < (k+1)T$$

$$h(kT-\tau) = a_n \tau^n + a_n - 1\tau^{(n-1)} + \ldots a_1 \tau + a_0$$

$$h(kT) = x(kT)$$

$$a_0 = x(kT)$$

$$h(kT-\tau) = x(kT)$$

$$\sigma = 0 \; t < 0$$

$$\sigma = 1 \; t \geqslant 0$$

$$h(t) = x(0)[\sigma(t) - \sigma(t-T)] + x(T)[\sigma(t-T) - \sigma(t-2T)] + x(2T)[\sigma(t-2T) - \sigma(t-3T)] \ldots x(nT)[\sigma(t-(n-1)T) - \sigma(t-nT)]$$

Continuo a discreto

- *Forward Difference:* $u(k+1) \approx u(k) + e(k) \cdot T$
- *Backward Difference:* $u(k+1) \approx u(k) + e(k+1) \cdot T$
- *Trapezoidal Approximation:* $u(k+1) \approx u(k) + \dfrac{\left[e(k+1) + e(k)\right]}{2} \cdot T$

  (Bilinear Transformation)
  (Tustin's Approximation)

- *Forward Difference:* $C(z) = \dfrac{U(z)}{E(z)} = \dfrac{T}{z-1} = \dfrac{Tz^{-1}}{1-z^{-1}}$
- *Backward Difference:* $C(z) = \dfrac{U(z)}{E(z)} = \dfrac{Tz}{z-1} = \dfrac{T}{1-z^{-1}}$
- *Trapezoidal Approximation:* $C(z) = \dfrac{U(z)}{E(z)} = \dfrac{T}{2}\dfrac{z+1}{z-1} = \dfrac{T}{2}\dfrac{1+z^{-1}}{1-z^{-1}}$

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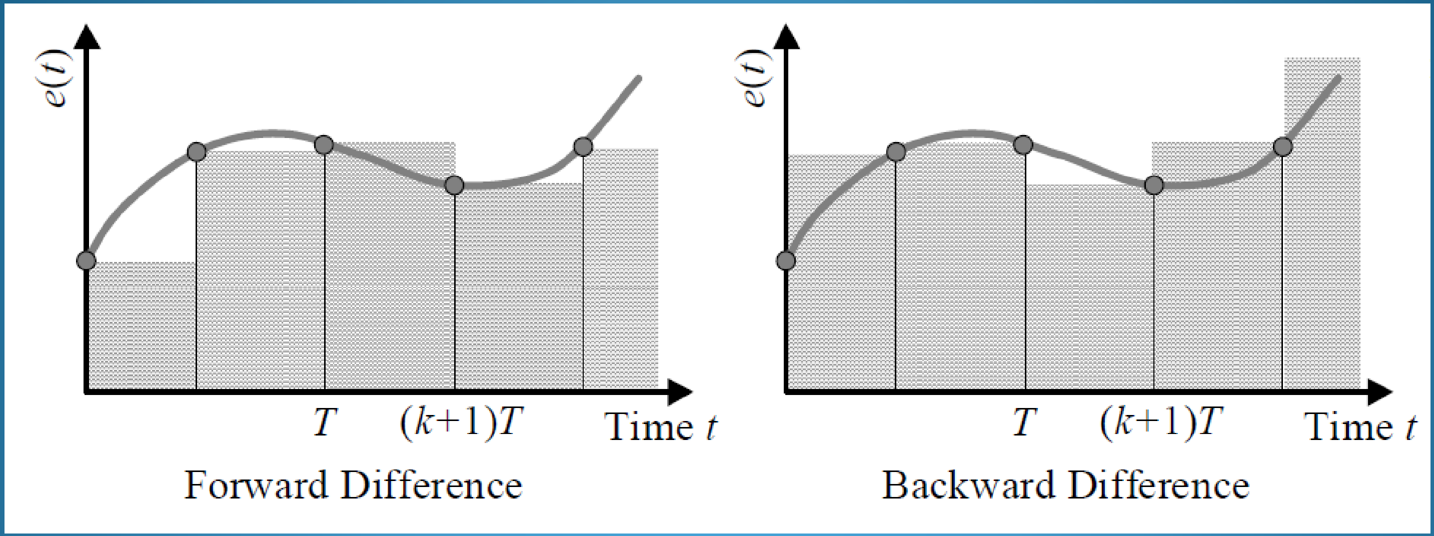
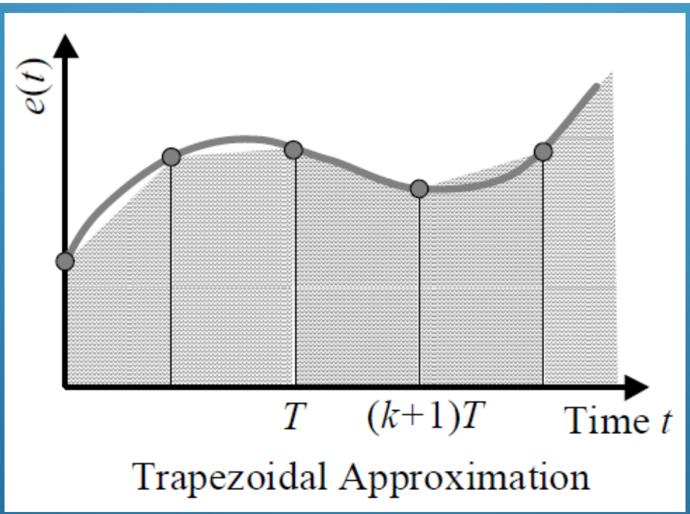
Continuo a discreto





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Continuo a discreto

- *Forward Difference:* $s \to \dfrac{z-1}{T}$ i.e. $C(z) = C(s)\big|_{s\to\frac{z-1}{T}}$

- *Backward Difference:* $s \to \dfrac{z-1}{Tz}$ i.e. $C(z) = C(s)\big|_{s\to\frac{z-1}{Tz}}$
- *Trapezoidal Approximation:* $s \to \dfrac{2}{T}\dfrac{z-1}{z+1}$ i.e. $C(z) = C(s)\big|_{s\to\frac{2}{T}\frac{z-1}{z+1}}$

$$C(s) = \frac{10s+1}{s+1}$$

Forward Difference: $C(z) = C(s)\big|_{s\to\frac{z-1}{T}} = \dfrac{10z-(10-T)}{z-(1-T)}$

Backward Difference: $C(z) = C(s)\big|_{s\to\frac{z-1}{Tz}} = \dfrac{(10+T)z-10}{(1+T)z-1}$

Trapezoidal Approximation: $C(z) = C(s)\big|_{s\to\frac{2}{T}\frac{z-1}{z+1}} = \dfrac{(20+T)z-(20-T)}{(2+T)z-(2-T)}$

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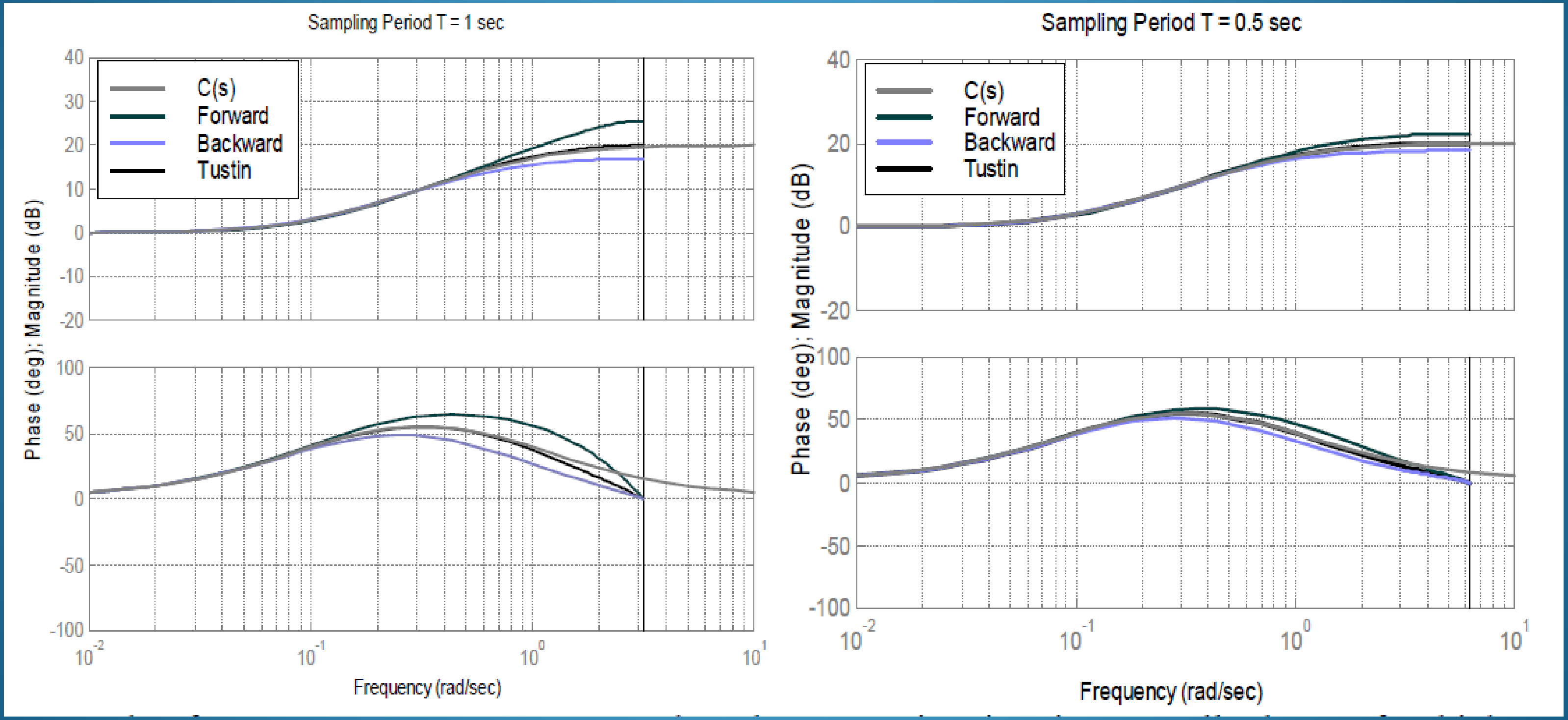
Continuo a discreto



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Realización de controladores y filtros digitales

Función de transferencia pulso y pasaje de tiempo continuo a tiempo discreto

```
>> num=[3 2 1];
>> den=[1 1 3 1];
>> s1=tf(num,den)

Transfer function:
  3 s^2 + 2 s + 1
--------------------
s^3 + s^2 + 3 s + 1

>> fz=tf(num,den,1e-3)

Transfer function:
  3 z^2 + 2 z + 1
--------------------
z^3 + z^2 + 3 z + 1

Sampling time: 0.001
```

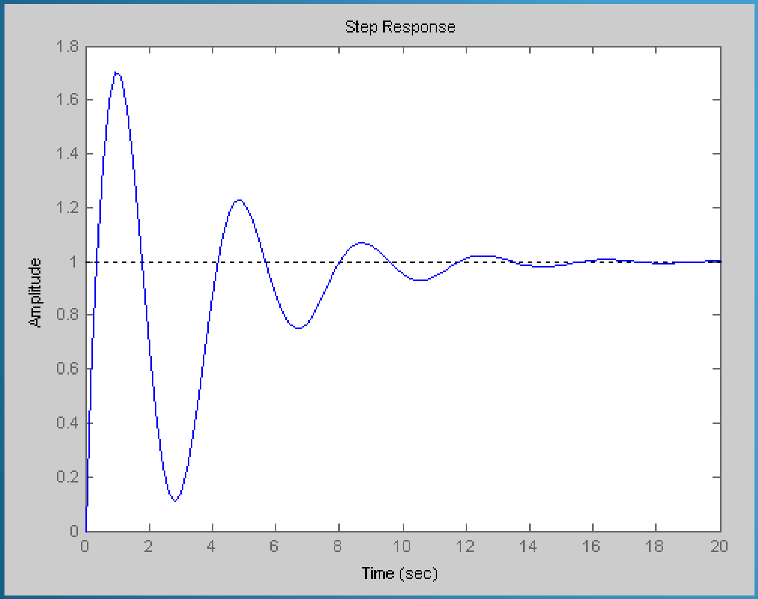
```
>> fz2=c2d(s1,1e-3,'tustin')

Transfer function:
0.0015 z^3 - 0.001499 z^2 - 0.0015 z + 0.001499
-----------------------------------------------
       z^3 - 2.999 z^2 + 2.998 z - 0.999

Sampling time: 0.001
```

```
>> fz2=c2d(s1,1e-3,'imp')

Transfer function:
   3 z^3 - 5.998 z^2 + 2.998 z
---------------------------------
z^3 - 2.999 z^2 + 2.998 z - 0.999

Sampling time: 0.001
>> fz2=c2d(s1,1e-3,'zoh')

Transfer function:
0.002999 z^2 - 0.005997 z + 0.002997
------------------------------------
 z^3 - 2.999 z^2 + 2.998 z - 0.999

Sampling time: 0.001
```

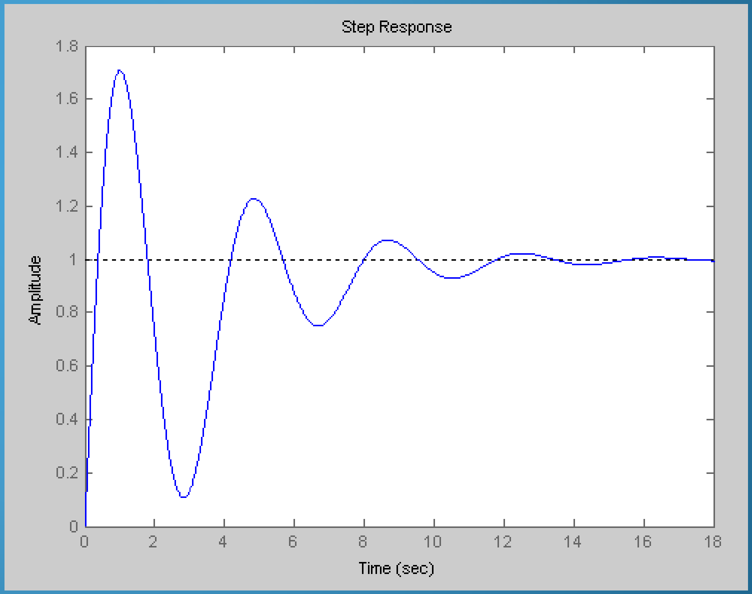
Realización de controladores y filtros digitales

Pasaje de una función en tiempo continuo a tiempo discreta con Matlab

Respuesta al escalón F(s)

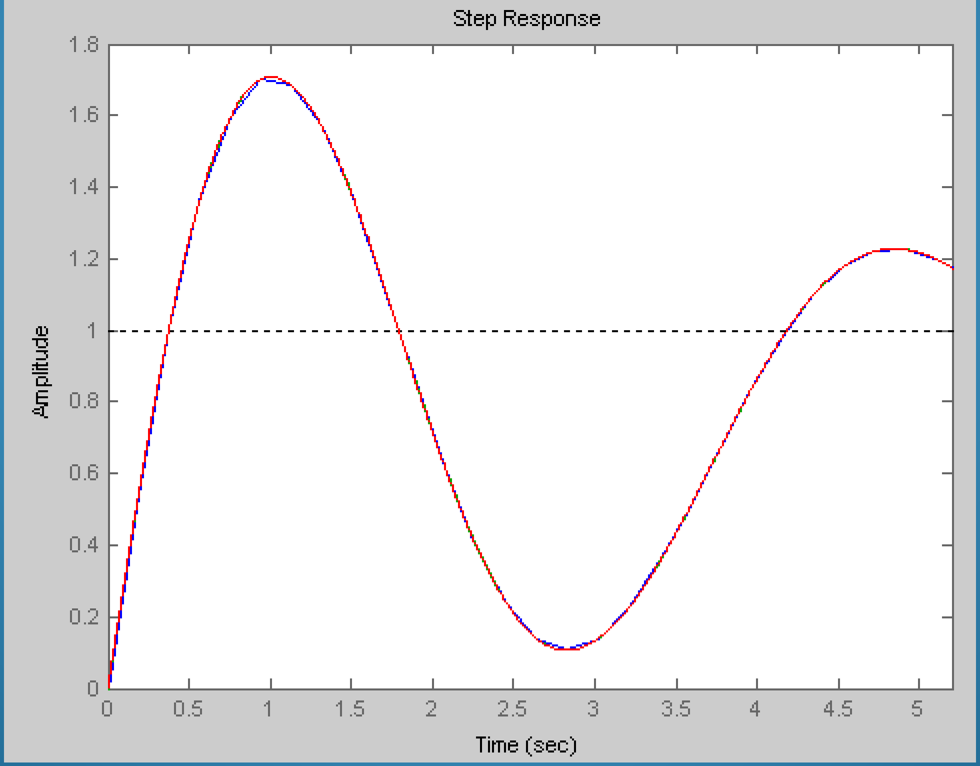


Respuesta al escalón F(z) ‘toustin’ Ts=1e-3



Realización de controladores y filtros digitales

Respuesta al escalon F(z) ‘zoh’ Ts=0.1 (Azul)
F(z) ‘tustin’ Ts=0.1 (rojo) t verde



Realización de controladores y filtros digitales

Diagrama en bloques de los filtros que involucren retardos, sumadores y restadores

Programación Directa : Utiliza un elemento de retraso por cada retraso que aparece en el numerador o denominador. Solo útil académicamente.

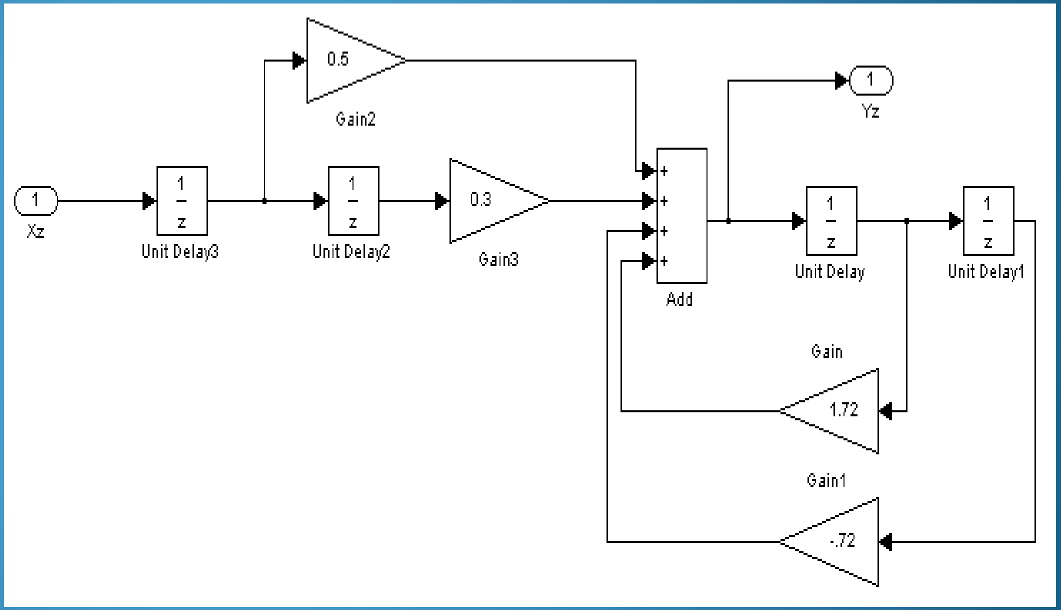
Programación estándar: Minimiza el numero de retardos.

Errores en la realización:

1. **Error de cuantificación de la señal de entrada.**
2. **Error por la acumulación en el redondeo de las operaciones aritméticas.**
3. **Error por cuantificación de coeficientes.**

Realización de controladores y filtros digitales

Programación Directa : Utiliza un elemento de retraso por cada retraso que aparece en el numerador o denominador. Solo útil académicamente.



$$\frac{Y}{X}=\frac{0.5z+0.3}{z^2-1.7z+.72}$$

$$\frac{Y}{X}=\frac{0.5z^{-1}+0.3z^{-2}}{1-1.7z^{-1}+.72z^{-2}}$$

$$Y(1-1.7z^{-1}+.72z^{-2})=(0.5z^{-1}+0.3z^{-2})X$$

Realización de controladores y filtros digitales

Programación estándar: Minimiza el numero de retardos.

$$\frac{Y}{X}=\frac{0.5z+0.3}{z^2-1.7z+.72}$$

$$\frac{Y}{X}=0.5z^{-1}+0.3z^{-2}\ \frac{1}{1-1.7z^{-1}+.72z^{-2}}\ \frac{H}{H}$$