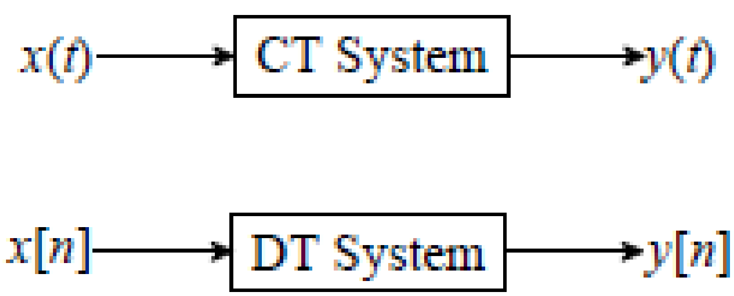
INTRODUCTION TO SYSTEM AND TYPES OF SYSTEMS

System

➢ System processes input signals to produce output signals

- For the most part, our view of systems will be from an input-output perspective:

  A system responds to applied input signals, and its response is described in terms of one or more output signals



How Are Signal & Systems Related

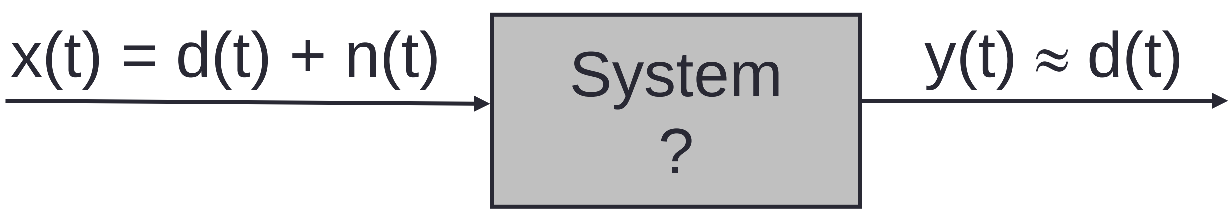
- How to design a system to process a signal in particular ways?

- Design a system to restore or enhance a particular signal
  - Remove **high frequency** background communication noise

- Assume a signal is represented as

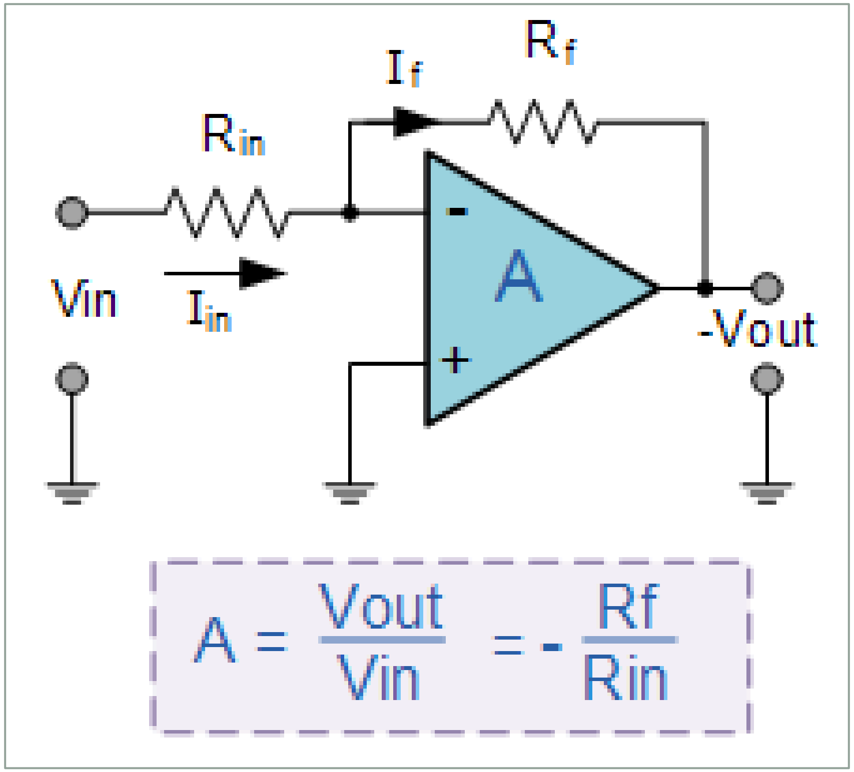
$$x(t) = d(t) + n(t)$$

- Design a system to remove the unknown "noise" component $n(t)$, so that $y(t) \approx d(t)$



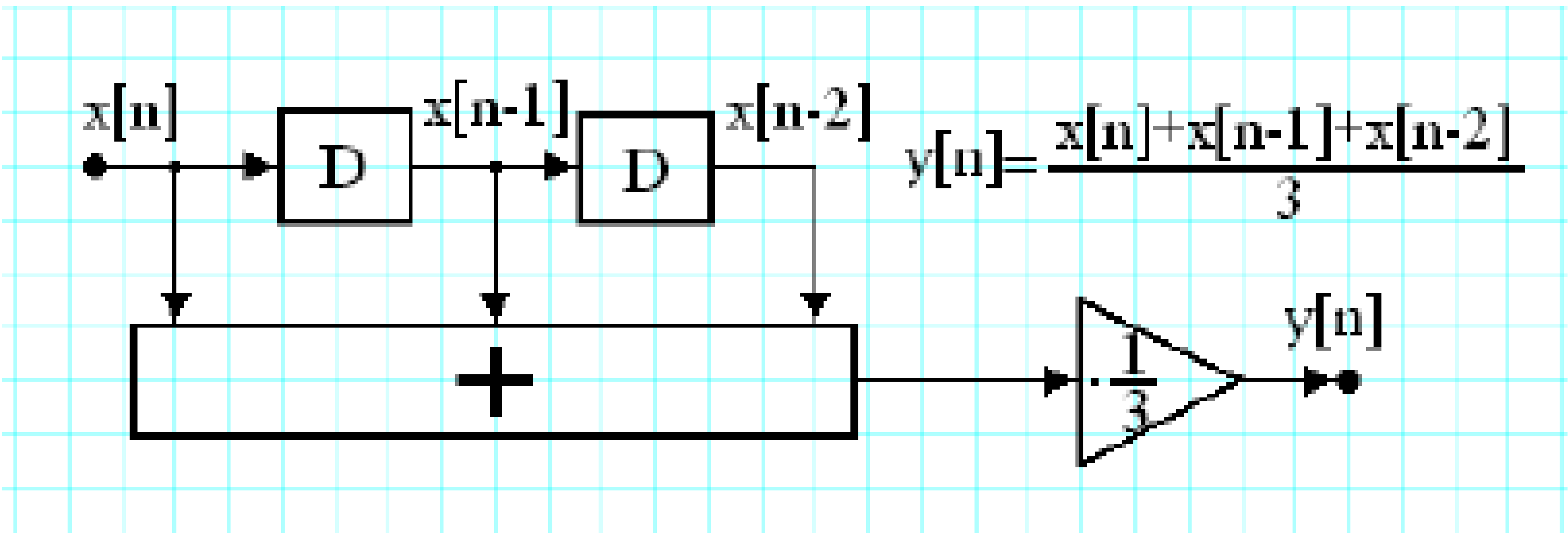
CT System Example

- Figure below shows an example of a continuous-time system
- The system is an operational amplifier, so the output is a scaled version of the input signal



DT System Example

- Figure below shows an example of a discrete-time system
- The system is a digital system and is called a moving average filter (running average), so the output is an average of the current and previous two inputs



System Properties - Memory

- a system is said to be memoryless if its output, for each value of the independent variable, at a given time is dependent only on the input at that same time, e.g.,

$$y[n] = \left(2x[n] - x^2[n]\right)^2 \qquad \text{memoryless}$$

- a resistor, R, with voltage $y(t)$ and current $x(t)$, obeys the relation:

$$y(t) = Rx(t) \qquad \text{memoryless}$$

System Properties - Memory

- a DT accumulator has the relationship:

$$y[n] = \sum_{k=-\infty}^{n} x[k] \qquad \text{memory}$$

- a capacitor, C, with input current, $x(t)$, and output voltage, $y(t)$, satisfies the relationship:

$$y(t) = \frac{1}{C} \int_{-\infty}^{t} x(\tau)\,d\tau \qquad \text{memory}$$

System Properties - Invertible

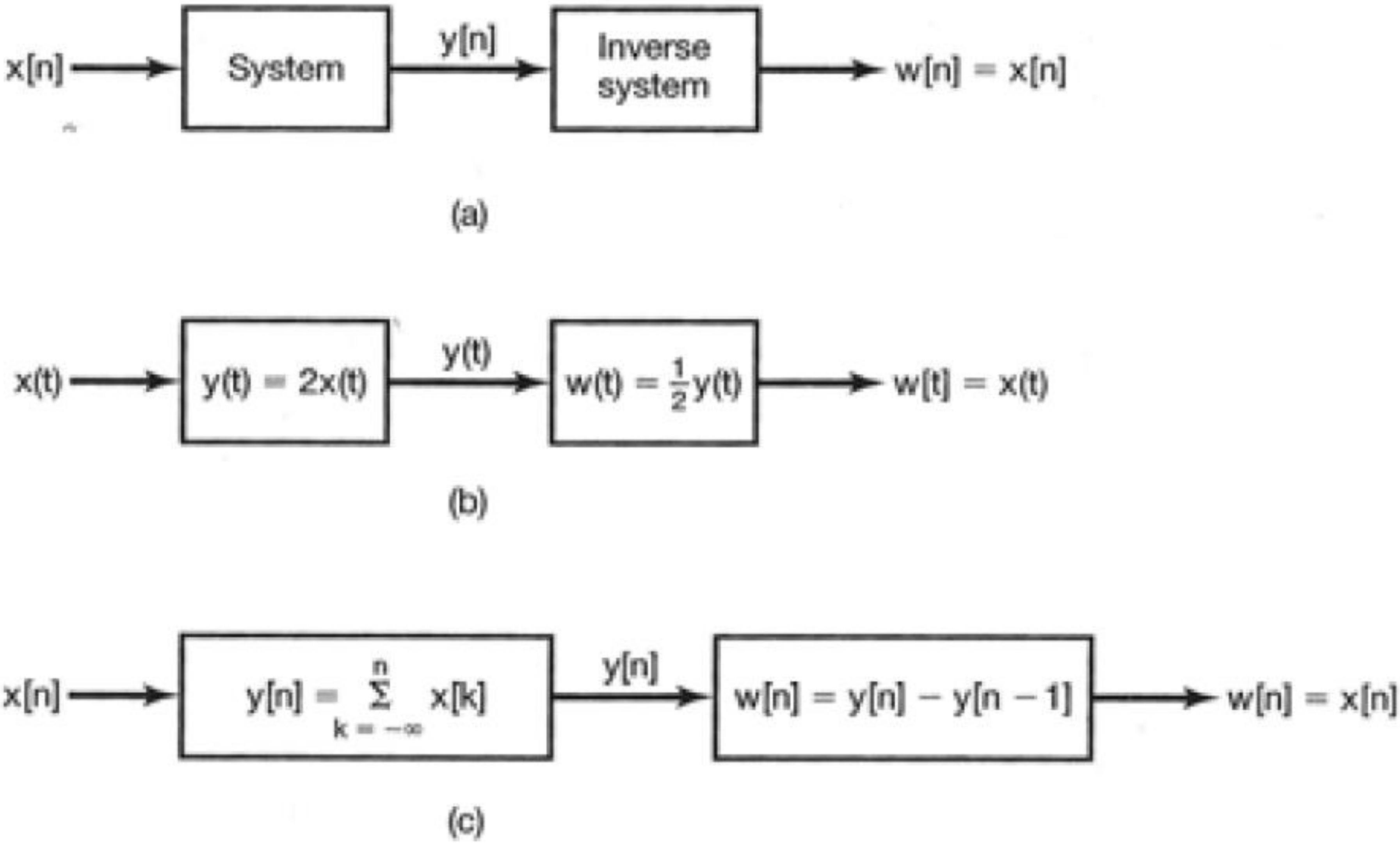
- A system is said to be invertible if distinct inputs lead to distinct outputs

- If a system is invertible, then there exists an inverse system that, when cascaded with the original system, yields an output $w[n]$ equal to the input $x[n]$ of the original system

– example: $y(t)=2x(t)$ with inverse $w(t)=y(t)/2$

– example: $y[n]=\sum_{k=-\infty}^{n} x[k]$ with inverse $w[n]=y[n]-y[n-1]$

System Properties - Invertible



System Properties - Invertible

- Are the two systems mentioned below Invertible or Non-invertible?

$$y[n] = 0$$

$$y(t) = x^2(t)$$

System Properties - Causality

- A system is **causal** if the output does not anticipate future values of the input
- Or in a Causal system, the output at any time depends only on the past and present values of the input
- **All** real-time physical systems are **causal**, because time only moves forward, effect occurs after cause
- Causality does not apply to systems processing recorded signals, e.g. taped sports games vs. live broadcast

System Properties - Causality

- Is the system defined by the equation below a Causal or Non-Causal?

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

System Properties - Causality

- Output $y[n_0]$ at positive time n_0 depends only on value of the input signal, $x[-n_0]$ at time $(-n_0)$; i.e., the past values

- Output $y[n_0]$ at negative time n_0 depends on value of the input signal, $x[-n_0]$ at positive time $(-n_0)$; i.e., the future values

- System is not causal

System Properties - Causality

- Is the system defined by the equation below a Causal or Non-Causal?

$$y(t) = x(t)\cos(t+1)$$

System Properties - Causality

- The output at time t equals the input at that same time multiplied by a number that varies with time

- We can rewrite the input-output relation as:

$$y(t) = x(t) \cdot g(t); \quad g(t) = \cos(t+1)$$

- We see that the current value of the input, $x(t)$, influences the current value of the output, $y(t)$, and thus this system is both causal and memoryless

System Properties – Causality Examples

EX 1 $y(t) = x^2(t-1)$

EX 2 $y(t) = x(t+1)$

EX 3 $y[n] = x[-n]$

EX 4 $y[n] = \left(\frac{1}{2}\right)^{n+1} x^3[n-1]$

System Properties - Causality

EX 1 $y(t) = x^2(t-1)$

E.g. $y(5)$ depends on $x(4)$ ... causal

EX 2 $y(t) = x(t+1)$

E.g. $y(5) = x(6), y$ depends on future $\Rightarrow$ noncausal

EX 3 $y[n] = x[-n]$

E.g. $y[5] = x[-5]$ ok, but
$y[-5] = x[5], y$ depends on future $\Rightarrow$ noncausal

EX 4 $y[n] = \left(\frac{1}{2}\right)^{n+1} x^3[n-1]$

E.g. $y[5]$ depends on $x[4]$ ... causal

END