

CENG 384 - Signals and Systems for Computer Engineers
Spring 2023
Homework 2

Geçit, Emre
e2521581@ceng.metu.edu.tr

Yancı, Baran
e2449015@ceng.metu.edu.tr

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1. (a)

$$y(t) = x(t) - 5\dot{y}(t)$$

(b)

$$y(t) = (e^{-t} + e^{-3t})u(t) - 5\dot{y}(t)$$

$$y(t) + 5\dot{y}(t) = (e^{-t} + e^{-3t})u(t)$$

$$y(t) = y_p(t) + y_h(t)$$

$$y_p(t) = Ke^{-t}u(t) + Le^{-3t}u(t)$$

$$Ke^{-t}u(t) + Le^{-3t}u(t) + 5(-Ke^{-t}u(t) - 3Le^{-3t}u(t)) = (e^{-t} + e^{-3t})u(t)$$

$$Ke^{-t}u(t) + Le^{-3t}u(t) - 5Ke^{-t}u(t) - 15Le^{-3t}u(t) = (e^{-t} + e^{-3t})u(t)$$

$$e^{-t}u(t)(K - 5K) + e^{-3t}u(t)(L - 15L) = (e^{-t} + e^{-3t})u(t)$$

$$K - 5K = 1$$

$$K = -1/4$$

$$L - 15L = 1$$

$$L = -1/14$$

$$y_p(t) = \frac{-1}{4}e^{-t}u(t) + \frac{-1}{14}e^{-3t}u(t)$$

$$y_h(t) = c_1e^{\alpha t}$$

$$c_1e^{\alpha t} + 5\alpha c_1e^{\alpha t} = 0$$

$$c_1 + 5\alpha c_1 = 0$$

$$\alpha = \frac{-1}{5}$$

$$y_h(t) = c_1e^{\frac{-1}{5}t}$$

$$y(t) = y_p(t) + y_h(t)$$

$$= \frac{-1}{4}e^{-t}u(t) + \frac{-1}{14}e^{-3t}u(t) + c_1e^{\frac{-1}{5}t}$$

$$y(0) = 0$$

$$0 = \frac{-1}{4} + \frac{-1}{14} + c_1$$

$$c_1 = \frac{9}{28}$$

$$y(t) = \frac{-1}{4}e^{-t}u(t) + \frac{-1}{14}e^{-3t}u(t) + \frac{9}{28}e^{\frac{-1}{5}t}$$

2. (a)

$$\begin{aligned}
y[n] &= x[n] * h[n] \\
&= \sum_{k=0}^n x[k]h[n-k] \\
&= \sum_{k=0}^n (2\delta[k] + \delta[k+1]) (\delta[n-(1+k)] + 2\delta[n+1-k]) \\
&= 2 \sum_{k=0}^n \delta[k]\delta[n-(1+k)] + 4 \sum_{k=0}^n \delta[k]\delta[n+1-k] + \sum_{k=0}^n \delta[k+1]\delta[n-(1+k)] + 2 \sum_{k=0}^n \delta[k+1]\delta[n+1-k] \\
&= 2\delta\left[\frac{n-1}{2}\right] + 4\delta\left[\frac{n+1}{2}\right] + \delta\left[\frac{n-2}{2}\right] + 2\delta\left[\frac{n}{2}\right]
\end{aligned}$$

(b)

$$\begin{aligned}
y(t) &= \frac{dx(t)}{dt} * h(t) \\
&= \frac{d}{dt} (u(t-1) + u(t+1)) * e^{-t} \sin(t)u(t) \\
&= (\delta(t-1) - \delta(t+1)) * e^{-t} \sin(t)u(t) \\
&= \int_{-\infty}^{\infty} (\delta(\tau-1) - \delta(\tau+1)) e^{-t-\tau} \sin(t-\tau) d\tau \\
&= \int_{-\infty}^{\infty} \delta(\tau-1) e^{-t-\tau} \sin(t-\tau) d\tau - \int_{-\infty}^{\infty} \delta(\tau+1) e^{-t-\tau} \sin(t-\tau) d\tau \\
&= e^{-t-1} \sin(t-1)u(t) + e^{-t+1} \sin(t+1)u(t)
\end{aligned}$$

3. (a)

$$\begin{aligned}
y(t) &= x(t) * h(t) \\
&= \int_{-\infty}^{\infty} x(\tau)h(t-\tau)d\tau \\
&= \int_{-\infty}^{\infty} x(t-\tau)h(\tau)d\tau \\
&= \int_{-\infty}^{\infty} e^{-(t-\tau)}e^{-2\tau}d\tau \\
&= \int_0^t e^{-(t-\tau)}e^{-2\tau}d\tau \\
&= e^{-t} \int_0^t e^{\tau}d\tau \\
&= e^{-t} (1 - e^{-t}) u(t)
\end{aligned}$$

(b)

$$\begin{aligned}
y(t) &= x(t) * h(t) \\
&= \int_{-\infty}^{\infty} x(\tau)h(t-\tau)d\tau \\
&= \int_{-\infty}^{\infty} x(t-\tau)h(\tau)d\tau \\
&= \int_{-\infty}^{\infty} (u(t-\tau) - u(t-(\tau+1))) e^{3\tau}d\tau \\
&= \int_{-\infty}^{\infty} u(t-\tau)e^{3\tau}d\tau - \int_{-\infty}^{\infty} u(t-(\tau+1))e^{3\tau}d\tau \\
&= \int_{-\infty}^t e^{3\tau}d\tau - \int_{-\infty}^{t-1} e^{3\tau}d\tau \\
&= \frac{e^{3t}}{3} - \frac{e^{3t-3}}{3}
\end{aligned}$$

4. (a)

$$\begin{aligned}
 y[n] - y[n-1] - y[n-2] &= 0 \\
 y[n] &= y[n-1] + y[n-2] \\
 y[2] &= y[1] - y[0] = 2 \\
 y[3] &= y[2] - y[1] = 3 \\
 y[4] &= y[3] - y[2] = 5 \\
 y[5] &= y[4] - y[3] = 8 \\
 &\dots
 \end{aligned}$$

It is the Fibonacci sequence.

$$y[n] = \frac{(1 + \sqrt{5})^n - (1 - \sqrt{5})^n}{2^n \sqrt{5}}$$

(b)

$$\begin{aligned}
 y^{(3)}(t) - 6y''(t) + 13y'(t) - 10y(t) &= 0 \\
 K^3 - 6K^2 + 13K - 10 &= 0 \\
 K(K-5)(K-2) + (K+5)(K-2) &= 0 \\
 (K-2)(K^2 - 4K + 5) &= 0
 \end{aligned}$$

$$K = 2, 2-j, 2+j$$

$$\begin{aligned}
 y_h(t) &= c_1 e^{2t} + c_2 e^{(2+j)t} + c_3 e^{(2-j)t} \\
 y_h(t) &= c_1 e^{2t} + c_2 (e^{2t} \cos(t) + j e^{2t} \sin(t)) + c_3 (e^{2t} \cos(t) - j e^{2t} \sin(t)) \\
 y_h(t) &= c_1 e^{2t} + c_2 e^{2t} \cos(t) + c_3 e^{2t} \cos(t) + c_2 j e^{2t} \sin(t) - c_3 j e^{2t} \sin(t) \\
 y_h(t) &= c_1 e^{2t} + (c_2 + c_3) e^{2t} \cos(t) + j(c_2 - c_3) e^{2t} \sin(t) \\
 y_h(t) &= C_1 e^{2t} + C_2 e^{2t} \cos(t) + C_3 e^{2t} \sin(t)
 \end{aligned}$$

$$\begin{aligned}
 y''(0) &= 3 \\
 &= 4C_1 + 3C_2 + 4C_3 \\
 y'(0) &= 1.5 \\
 &= 2C_1 + 2C_2 + C_3 \\
 y(0) &= 1 \\
 &= C_1 + C_2
 \end{aligned}$$

$$\begin{aligned}
 C_1 &= 2 \\
 C_2 &= -1 \\
 C_3 &= -0.5
 \end{aligned}$$

$$y_h(t) = 2e^{2t} - e^{2t} \cos(t) - \frac{1}{2}e^{2t} \sin(t)$$

5. (a)

$$\begin{aligned}
 y''(t) + 5y'(t) + 6y(t) &= \cos(5t) \\
 &= \frac{e^{j5t} - e^{-j5t}}{2} \\
 &= \frac{e^{j5t}}{2} - \frac{e^{-j5t}}{2}
 \end{aligned}$$

$$y_p(t) = c_1 e^{j5t} + c_2 e^{-j5t}$$

$$\begin{aligned} -25c_1 e^{j5t} - 25c_2 e^{-j5t} + 25j c_1 e^{j5t} - 25j c_2 e^{-j5t} + 6c_1 e^{j5t} + 6c_2 e^{-j5t} &= \frac{e^{j5t}}{2} - \frac{e^{-j5t}}{2} \\ e^{j5t} (-19c_1 + 25j c_1) + e^{-j5t} (-19c_2 - 25j c_2) &= \frac{e^{j5t}}{2} - \frac{e^{-j5t}}{2} \end{aligned}$$

$$(-19c_1 + 25j c_1) = (-19c_2 - 25j c_2) = \frac{1}{2}$$

$$\begin{aligned} c_1 &= \frac{1}{50j - 38} \\ c_2 &= \frac{-1}{50j + 38} \\ y_p(t) &= \frac{1}{50j - 38} e^{j5t} - \frac{1}{50j + 38} e^{-j5t} \end{aligned}$$

(b)

$$\begin{aligned} y''(t) + 5y'(t) + 6y(t) &= 0 \\ K^2 + 5K + 6 &= 0 \\ K &= -3, -2 \end{aligned}$$

$$y_h(t) = c_1 e^{-3t} + c_2 e^{-2t}$$

(c)

$$\begin{aligned} y(t) &= y_p(t) + y_h(t) \\ &= \frac{1}{50j - 38} e^{j5t} - \frac{1}{50j + 38} e^{-j5t} + c_1 e^{-3t} + c_2 e^{-2t} \end{aligned}$$

$$\begin{aligned} y(0) = y'(0) &= 0 \\ \frac{1}{50j - 38} - \frac{1}{50j + 38} + c_1 + c_2 &= 0 \\ \frac{5j}{50j - 38} + \frac{5j}{50j + 38} - 3c_1 - 2c_2 &= 0 \end{aligned}$$

$$\begin{aligned} c_1 &= \frac{3}{34} \\ c_2 &= \frac{-2}{29} \end{aligned}$$

$$y(t) = \frac{1}{50j - 38} e^{j5t} - \frac{1}{50j + 38} e^{-j5t} + \frac{3}{34} e^{-3t} - \frac{2}{29} e^{-2t}$$

6. (a)

$$w[n] - \frac{1}{2}w[n-1] = x[n]$$

$$w[n] = 0, \forall n < 0$$

$$w[0] - \frac{1}{2}w[-1] = x[0]$$

$$w[0] = x[0]$$

$$w[1] - \frac{1}{2}w[0] = x[1]$$

$$w[1] = x[1] + \frac{1}{2}x[0]$$

$$w[2] - \frac{1}{2}w[1] = x[2]$$

$$w[2] = x[2] + \frac{1}{2}x[1] + \frac{1}{4}x[0]$$

...

$$w[n] = \sum_{k=0}^n 2^{-k}x[n-k]$$

$$h_0[n] = \sum_{k=0}^n 2^{-k}\delta[n-k]$$

$$= 2^{-n}$$

$$(\delta[n-k] = 0 \text{ for } k \neq n)$$

(b) If we feed the first system with the unit impulse, we get $h_0[n]$. If we feed the second system with $h_0[n]$, we get

$$\begin{aligned} h[n] &= \sum_{k=0}^n 2^{-k}2^{-n+k} \\ &= \sum_{k=0}^n 2^{-n} \\ &= (n+1) * 2^{-n} \end{aligned}$$

(c)

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

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

$$= \sum_{k=0}^{\infty} x[n-k]h[k]$$

$$(h[k] = 0 \text{ for } k < 0)$$

$$= \sum_{k=0}^{\infty} x[k] * (n+1) * 2^{k-n}$$

7. (a)

(b)