Toronto Metropolitan University
Department of Electrical, Computer, & Biomedical Engineering
Faculty of Engineering & Architectural Science

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Part A: Impulse Response

A.1 Characteristic Polynomial

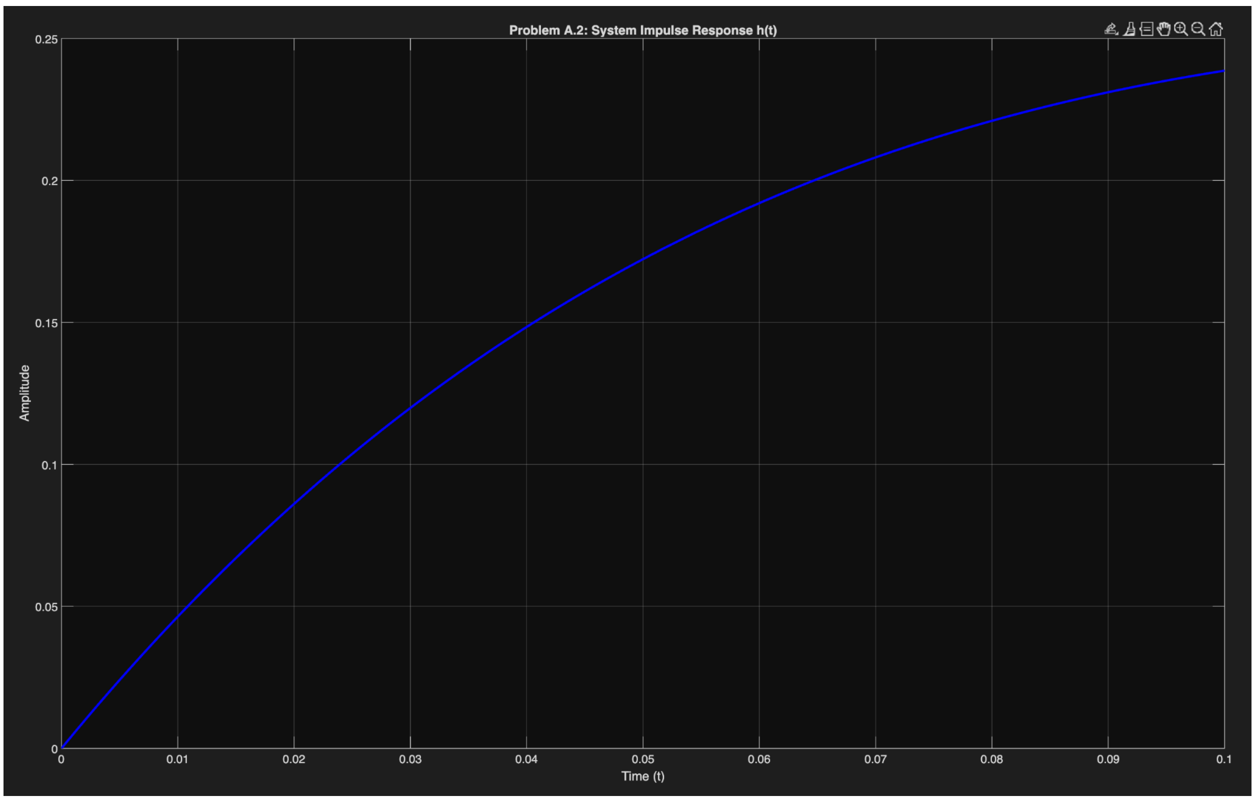
For a system with characteristic values (eigenvalues) given by lambda = [-5, -10], the poly function in MATLAB was used to find the corresponding characteristic polynomial.

Result: The MATLAB command poly([-5, -10]) returned the vector [1 15 50]. This corresponds to the characteristic polynomial:

$s^2 + 15s + 50 = 0$

A.2 Impulse Response Plot

The impulse response of the system defined in A.1 was plotted over the time interval t = [0, 0.1].



[Figure 1: Impulse Response h(t) for the system defined in Problem A.1.]

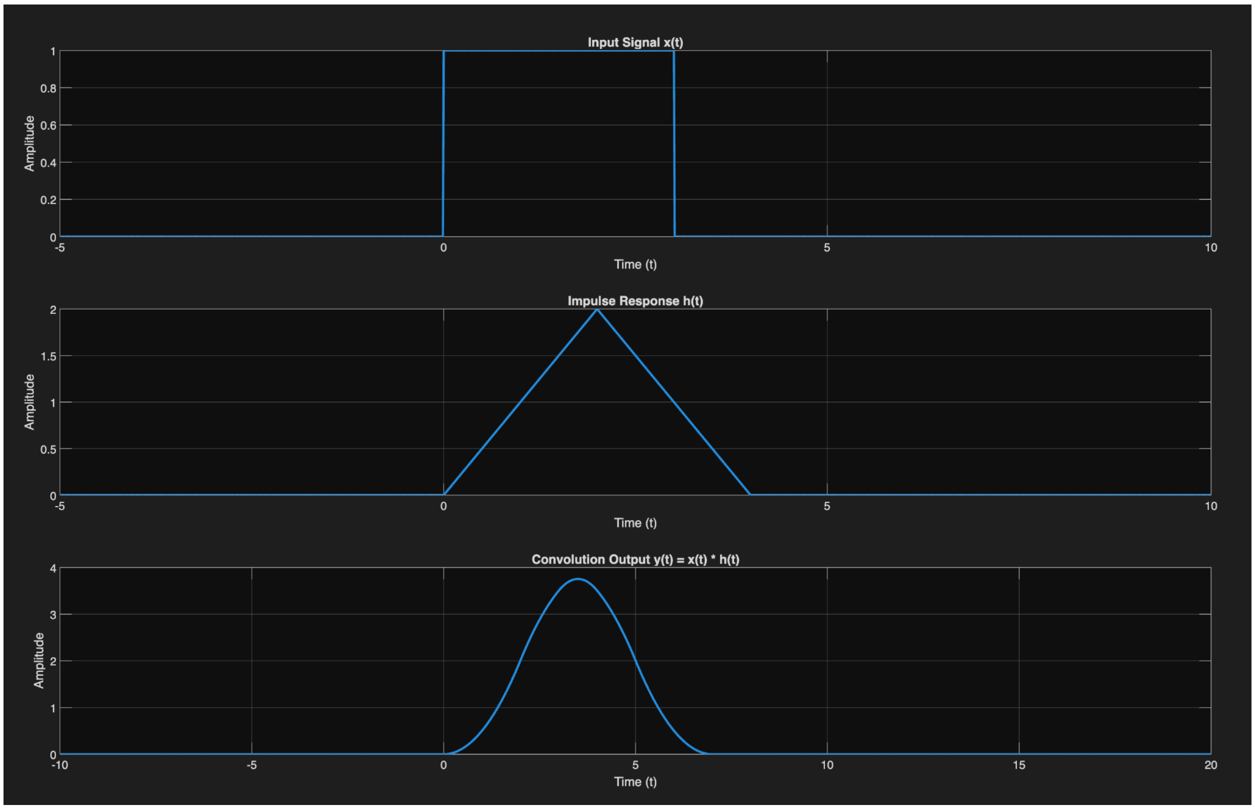
Analysis:

Figure 1 shows the impulse response of the system. The response starts at zero, rises to a peak, and then decays back towards zero. This behavior is characteristic of an overdamped second-order system. The two negative, real eigenvalues (-5 and -10) correspond to two decaying exponential terms in the response. Since both eigenvalues have negative real parts, the impulse response decays to zero as $t \to \infty$, indicating that the system is STABLE.

Part B: Convolution

B.2 Convolution of Rectangular and Triangular Signals

The convolution of a rectangular input signal x(t) (duration 3 seconds) and a triangular impulse response h(t) (duration 4 seconds) was performed.



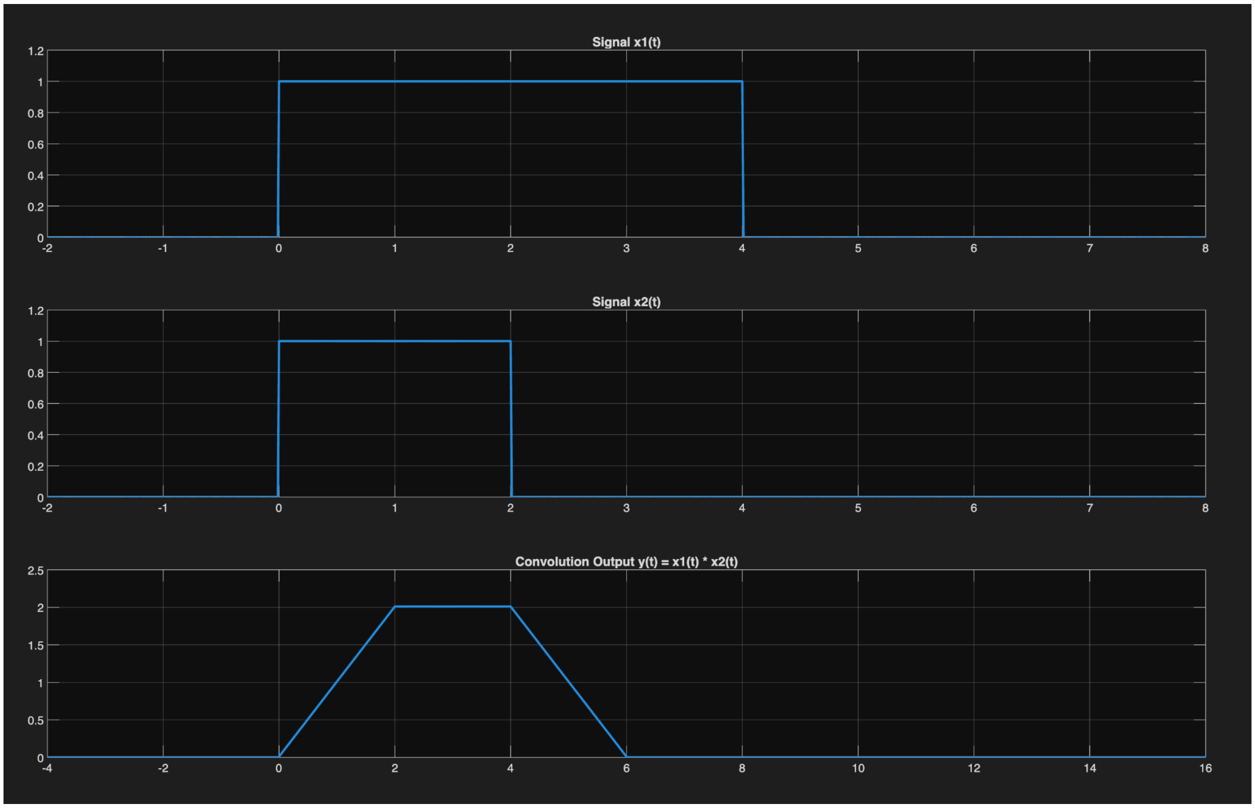
[Figure 2: Convolution of x(t) and h(t) from Problem B.2.]

Analysis:

Figure 2 displays the input signal x(t), the impulse response h(t), and the resulting output y(t). The output signal y(t) is a smoothed version of the input, with its shape determined by the integration process of convolution. The duration of the output signal is 7 seconds, which is the sum of the durations of the input signal (3s) and the impulse response (4s).

B.3 Convolution of Two Rectangular Signals

The convolution of two rectangular signals, x1(t) (duration 4 seconds) and x2(t) (duration 2 seconds), was performed.



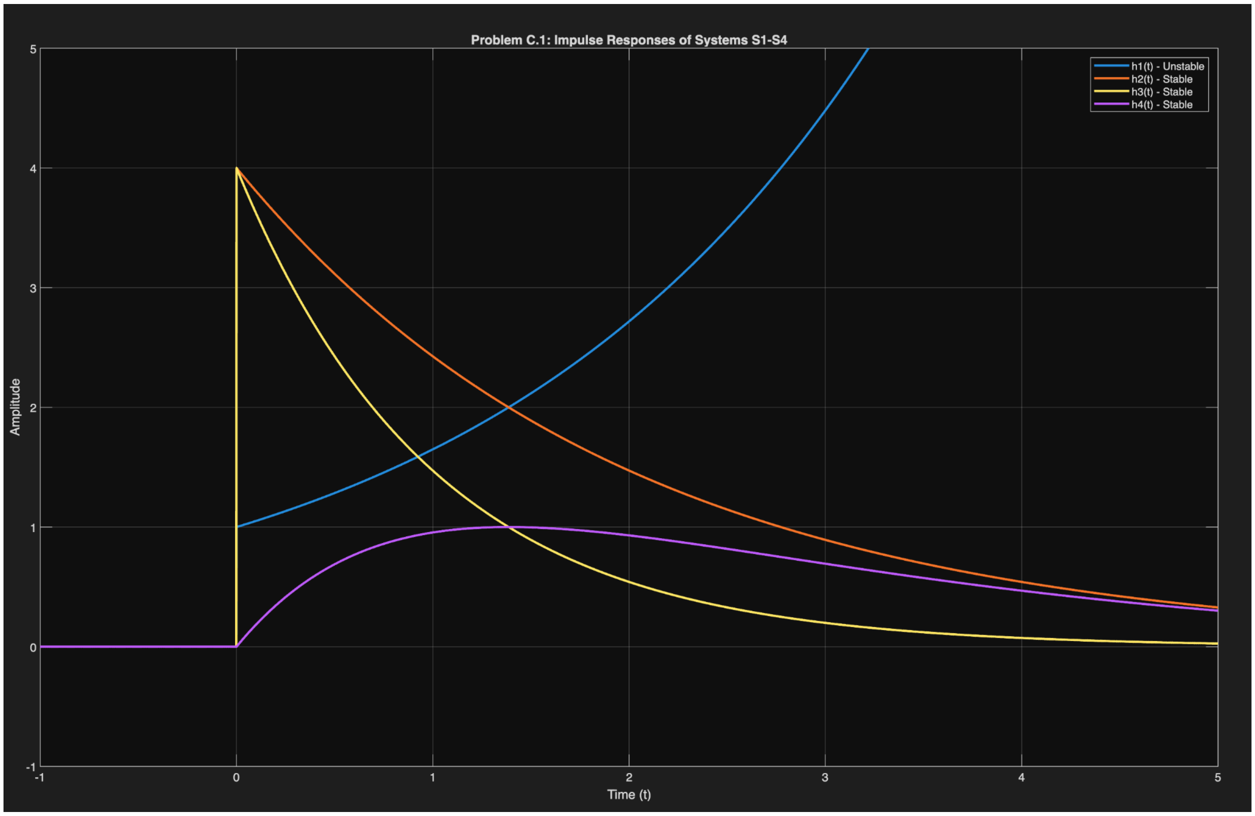
[Figure 3: Convolution of x1(t) and x2(t) from Problem B.3.]

Analysis:

Figure 3 shows that the convolution of two rectangular pulses results in a trapezoidal pulse. The output signal y(t) starts at t=0, ramps up linearly to a constant value, and then ramps down linearly to zero. The total duration of the output is 6 seconds, which is consistent with the sum of the durations of x1(t) (4s) and x2(t) (2s).

Part C: System Behavior and Stability

C.1 & C.2 Impulse Responses and Characteristic Values
The impulse responses for four different LTI systems (S1, S2, S3, S4) were plotted.



[Figure 4: Impulse responses for systems S1, S2, S3, and S4.]

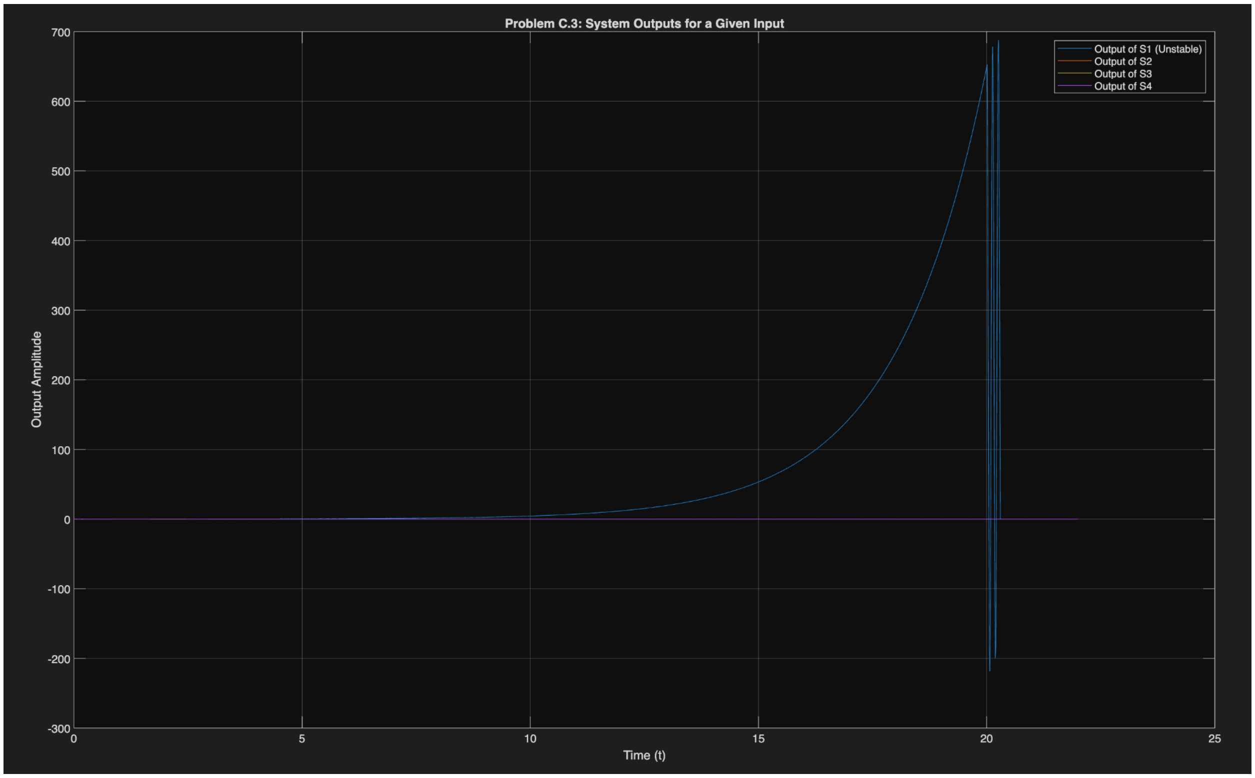
Analysis:
The stability of each system can be determined directly from its impulse response and its characteristic values (the coefficients in the exponential terms):

- System S1: h1(t) = e^(0.5t)u(t). The characteristic value is λ = 0.5. As seen in Figure 4, the impulse response grows exponentially without bound. This represents an UNSTABLE system.
- System S2: h2(t) = 4e^(-0.5t)u(t). The characteristic value is λ = -0.5. The impulse response decays to zero, indicating a STABLE system.
- System S3: h3(t) = 4e^(-t)u(t). The characteristic value is λ = -1. The impulse response decays to zero faster than S2, indicating a STABLE system.
- System S4: h4(t) = 4(e^(-0.5t) - e^(-t))u(t). The characteristic values are λ = -0.5, -1. The impulse response is a combination of two decaying exponentials and decays to zero, indicating a STABLE system.

A system is stable if its impulse response is absolutely integrable, which for these systems requires the real parts of all characteristic values to be negative.

C.3 System Outputs for a Given Input

Each system was given the input signal x(t) = [u(t) – u(t − 3)] sin(5t). The output of each system was calculated via convolution.



[Figure 5: System outputs y1(t) through y4(t) for the given input x(t).]

Analysis:

The output plots in Figure 5 confirm the stability analysis from C.1:

- Output of S1: The output y1(t) grows without bound, even after the input signal has ended. This is the expected behavior of an unstable system receiving a bounded input.
- Outputs of S2, S3, S4: The outputs y2(t), y3(t), and y4(t) are all bounded and eventually decay towards zero after the input is finished. This demonstrates the Bounded-Input, Bounded-Output (BIBO) stability of these systems.

Furthermore, there is a clear relationship between the outputs of systems S2, S3, and S4. The impulse responses are related by h4(t) = h2(t) - h3(t). Due to the linearity property of LTI systems, the outputs must also be related by y4(t) = y2(t) - y3(t). This relationship is visually confirmed in the plot, where the graph of y4(t) is the point-by-point difference between the graphs of y2(t) and y3(t).