```
y2 = filter(num2, den2, x);
y = y1 + y2; % filter output
% first section
[L1_inf L1_1 L1_2] = norms(
    num1, den1);
% second section
[L2_inf L2_1 L2_2] = norms(
    num2, den2);
% inputs for first and second section
x1=x/L1_1; num1_1=L1_1*num1;
num2_1=L2_1*num2; x2=x/L2_1;
% output from first section
y1_1=filter(num1_1,den1,x1);
% output from second section
y2_1=filter(num2_1,den2,x2);
y_L1 = y1_1 + y2_1;
subplot(211); plot(n,x,'-r');
hold on      plot(n,x1,'--g');
hold on      plot(n,x2,'-.m');
hold off; legend('x(n)-input'
    ,'x_1(n)-input to H_1(z)',
    'x_2(n)-input to H_2(z)');
subplot(212);
plot(n,y1_1,'-.g');  hold on
plot(n,y2_1,':m');   hold on
plot(n,y_L1,'--b'); hold off;
title('Parallel
    implementation - L_1');
ylabel('Amplitude');
legend('y1(n)-output from H_1
    (z)', 'y2(n)-output from
    H_2(z)','y(n)-output',0);
```

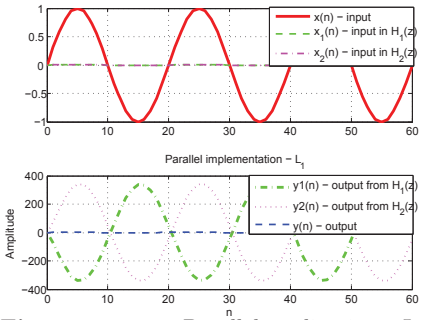

Figure 13.29: Parallel realization, L_1 norm - input and output sequences

13.4 Exercises

1. Next IIR systems are considered:

$$H_1(z) = \frac{1-2\cos\frac{2\pi}{6}z^{-1}+z^{-2}}{1-1.4\cos\frac{2\pi}{6}z^{-1}+0.49z^{-2}} \cdot \frac{1-2\cos\frac{2\pi}{4}z^{-1}+z^{-2}}{1-1.2\cos\frac{2\pi}{4}z^{-1}+0.36z^{-2}};$$

$$H_2(z) = \frac{0.5+0.2z^{-1}-0.3z^{-2}+0.1z^{-3}+z^{-4}}{1+0.1z^{-1}-0.3z^{-2}+0.2z^{-3}+0.5z^{-4}}.$$

   - Determine the coefficients of the numerator and denominator polynomials, and sketch the pole-zero diagram and the frequency response characteristics;
   - For the direct-form quantize (using truncation) the transfer function coefficients on 15, 8 and 4 bits. Note the values obtained for each case;

   (a) Sketch the pole-zero diagram and the frequency response characteristics for the transfer functions with quantized coefficients;

   (b) Compare the frequency response characteristics of the filters with unquantized coefficients with those with quantized coefficients. How many bits are necessarily for the coefficients' representation such that

this limitation do not affect much the magnitude characteristic?

- Determine the parallel-form of the given transfer functions;

(a) Quantize the coefficients of each function from the structure on 15, 8 and 4 bits. Note the values obtained for each case;

(b) Evaluate the global transfer function summing all the transfer functions with quantized coefficients and plot the global frequency response and compare the results with the one previously obtained;

- Determine the cascade-form of the given transfer functions;

(a) Quantize the coefficients of each function from the structure on 15, 8 and 4 bits. Note the values obtained for each case;

(b) Evaluate the global transfer function multiplying all the transfer functions with quantized coefficients;

(c) Sketch the pole-zero diagram and the global frequency response and compare the results with the one obtained for the direct-form;

- Determine the lattice structure of the given transfer functions;

(a) Quantize the coefficients of each function from the structure on 15, 8 and 4 bits. Note the values obtained for each case;

(b) Evaluate the global transfer function and plot the pole-zero diagram and the global frequency response; compare the results with the one previously obtained.

2. Redo example `L13_7` using 5 bits for quantization. What can you notice for $a = 1/4$ and $a = -3/4$?

3. Redo example `L13_7` using 5 bits for quantization. What can you notice if the number of bits is 5?

4. Redo example `L13_12` for L_∞ and L_1 norms. What can you notice?

5. Redo example `L13_13` for L_∞ and L_2 norms. What can you notice?