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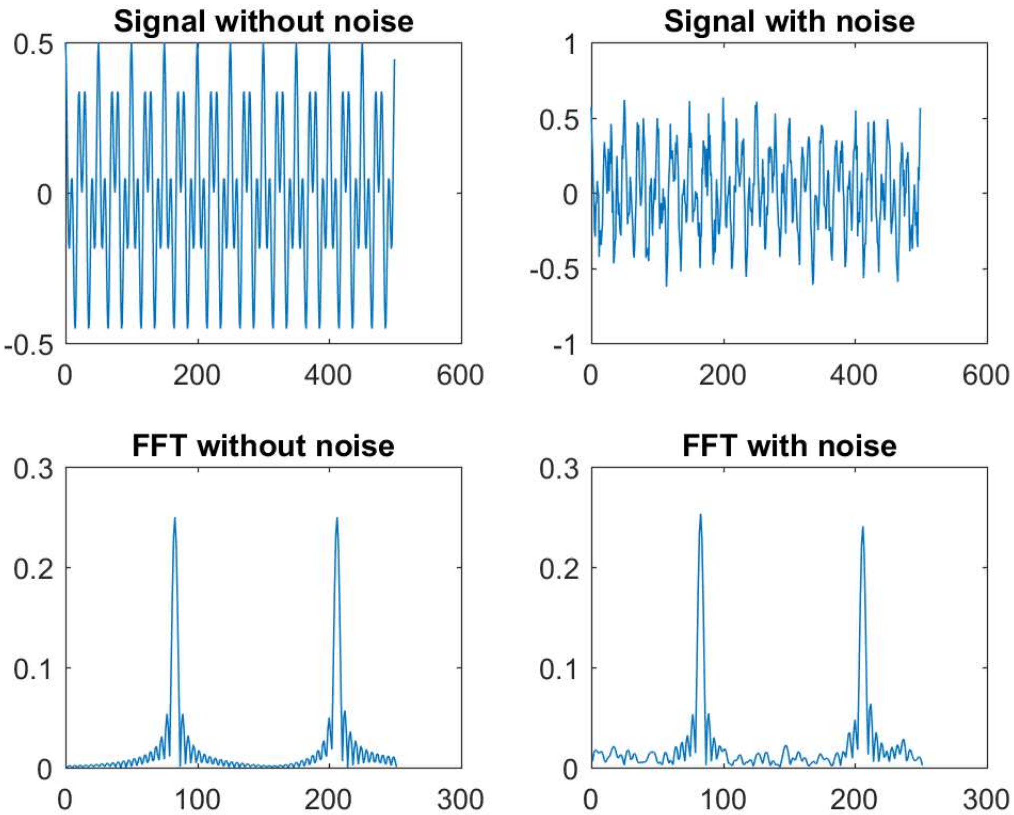
Problem 4 - a

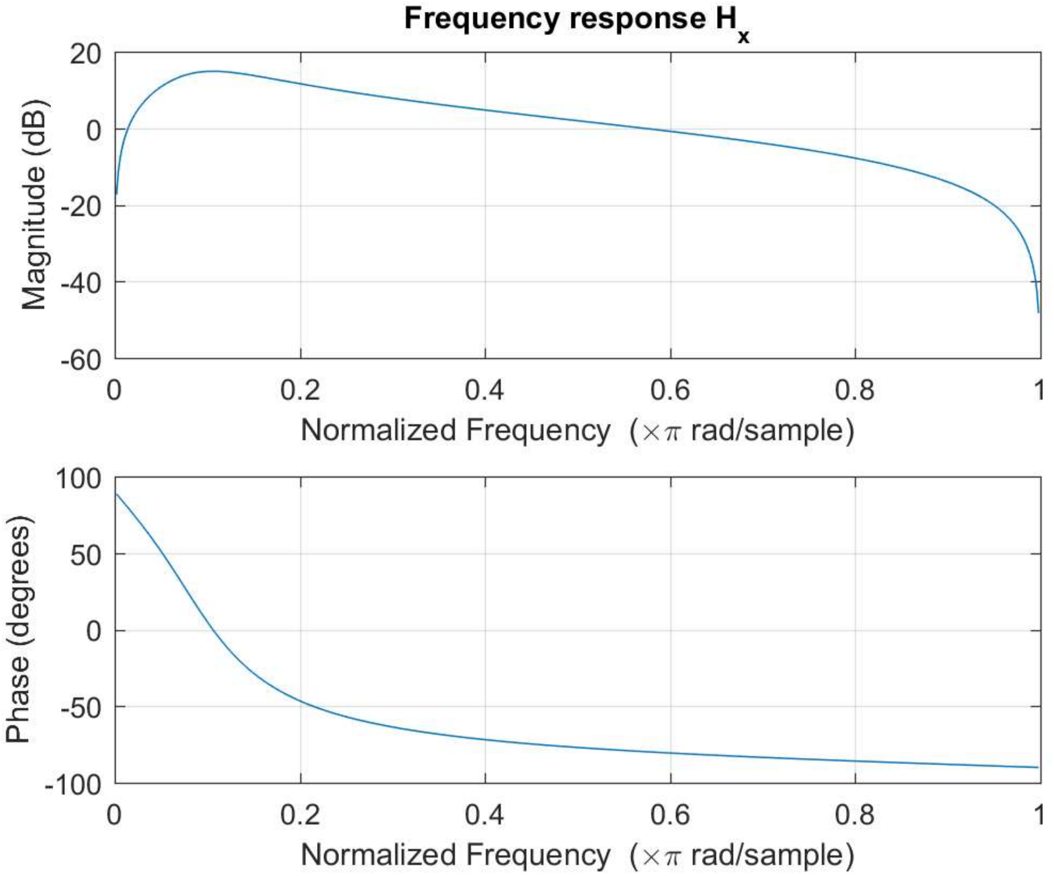
```
Ax = 0.25;
Ay = 0.25;
Anoise = 0.1; % amplitude of noise
fx = 0.04;
fy = 0.10;
L  = 500;
n = 0:1:(L-1);


d = Ax*cos(2*pi()*fx*n) + Ay*cos(2*pi()*fy*n);
e = Anoise*randn(size(d));

FFT_N = 2048;

% without noise
Y = fft(d, FFT_N);
P2 = abs(Y/L); % two sided spectrum
P1 = P2(1:L/2+1);
P1(2:end-1) = 2*P1(2:end-1); % P1 = one sided spectrum

subplot(2,2,1);
plot(n, d);  title('Signal without noise');
subplot(2,2,3);
plot(P1);   title('FFT without noise');

% with noise
Y = fft(d+e, FFT_N);
P2 = abs(Y/L); % two sided spectrum
P1 = P2(1:L/2+1);
P1(2:end-1) = 2*P1(2:end-1); % P1 = one sided spectrum

subplot(2,2,2);
plot(n, d+e);  title('Signal with noise');
subplot(2,2,4);
plot(P1);   title('FFT with noise');
```

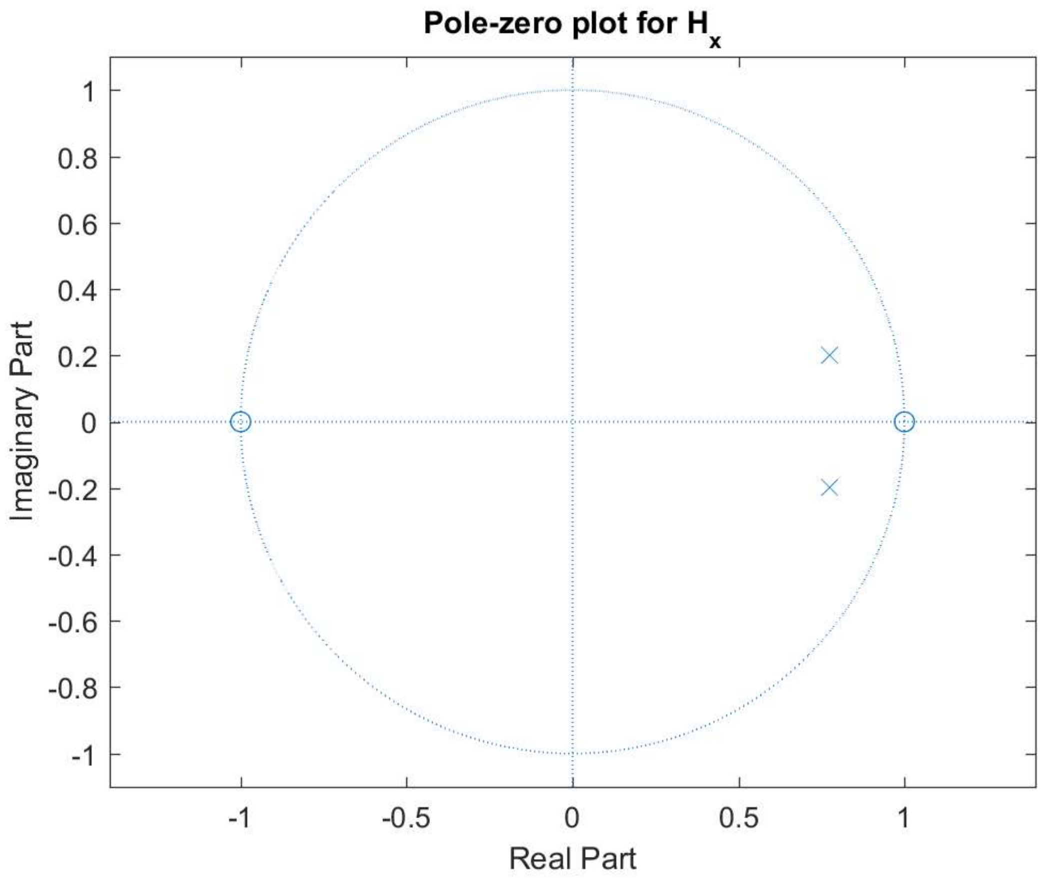


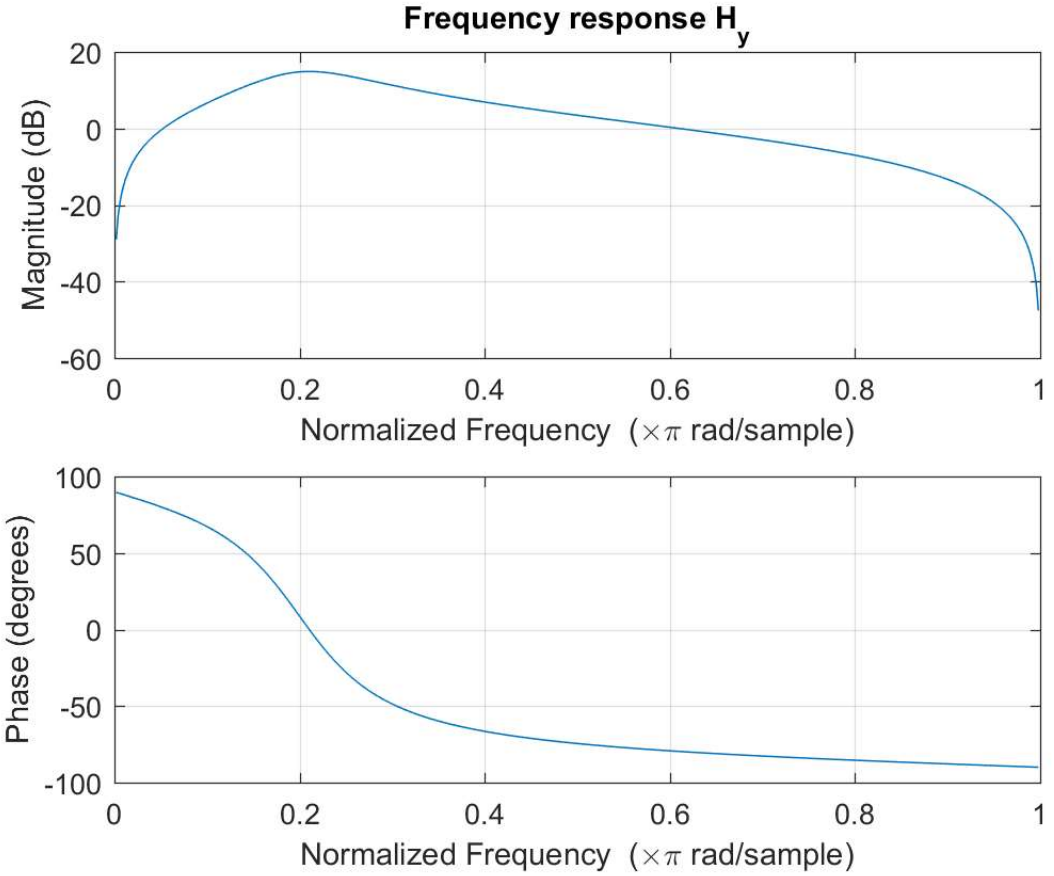
Problem 4 - Digital resonators

```
alpha = 0.8; % distance from origin to pole

% x resonator
wx = 2*pi()*fx;
px = alpha*exp(i*wx);
Hx_B = [1 0 -1];
Hx_A = [1 -2*alpha*cos(wx) alpha^2];

% y resonator
wy = 2*pi()*fy;
py = alpha*exp(i*wy);
Hy_B = [1 0 -1];
Hy_A = [1 -2*alpha*cos(wy) alpha^2];

figure(); freqz(Hx_B, Hx_A);  title('Frequency response H_x');
figure(); zplane(Hx_B, Hx_A); title('Pole-zero plot for H_x')
figure(); freqz(Hy_B, Hy_A);  title('Frequency response H_y');
figure(); zplane(Hy_B, Hy_A); title('Pole-zero plot for H_y');

qx = filter(Hx_B, Hx_A, d+e);
qy = filter(Hy_B, Hy_A, d+e);

figure();
% raw
Y = fft(d+e, FFT_N);
P2 = abs(Y/L); % two sided spectrum
P1 = P2(1:L/2+1);
P1(2:end-1) = 2*P1(2:end-1); % P1 = one sided spectrum

subplot(2,4,1);
plot(n, d+e); title('Raw data');
```

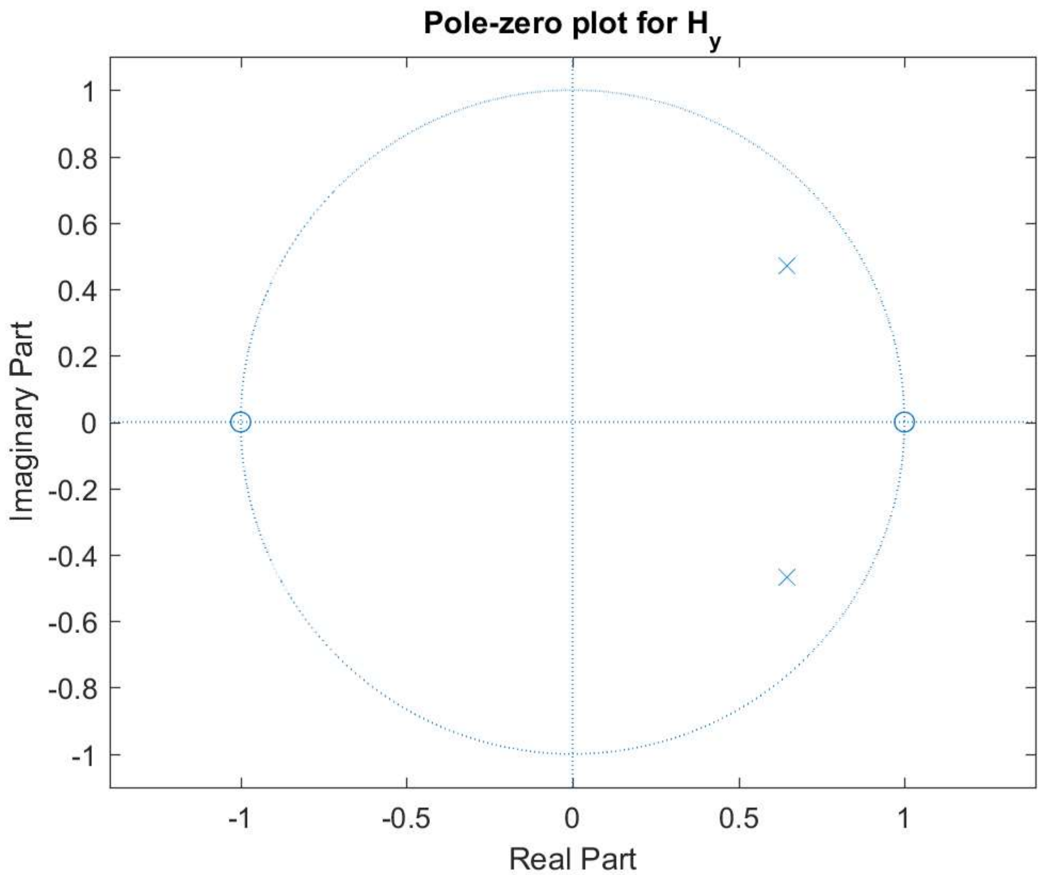
```
subplot(2,4,5);
plot(P1); title('FFT of raw');


% x-filter
Y = fft(qx, FFT_N);
P2 = abs(Y/L); % two sided spectrum
P1 = P2(1:L/2+1);
P1(2:end-1) = 2*P1(2:end-1); % P1 = one sided spectrum

subplot(2,4,2);
plot(n, qx); title('Output from q_x');
subplot(2,4,6);
plot(P1); title('FFT for q_x');

% y-filter
Y = fft(qy, FFT_N);
P2 = abs(Y/L); % two sided spectrum
P1 = P2(1:L/2+1);
P1(2:end-1) = 2*P1(2:end-1); % P1 = one sided spectrum

subplot(2,4,3);
plot(n, qy);  title('Output from q_y');
subplot(2,4,7);
plot(P1);   title('FFT for q_y');


% both resonators
T = filter(Hx_B, Hx_A, d+e);
T = filter(Hy_B, Hy_A, T);
Y = fft(T, FFT_N);
P2 = abs(Y/L); % two sided spectrum
P1 = P2(1:L/2+1);
P1(2:end-1) = 2*P1(2:end-1); % P1 = one sided spectrum

subplot(2,4,4);
plot(n, T); title('Output');
subplot(2,4,8);
plot(P1);   title('FFT of output');
```


Frequency response H_x
Magnitude (dB)
20
0
-20
-40
-60
0
0.2
0.4
0.6
0.8
1
Normalized Frequency ($\times\pi$ rad/sample)
Phase (degrees)
100
50
0
-50
-100
0
0.2
0.4
0.6
0.8
1
Normalized Frequency ($\times\pi$ rad/sample)

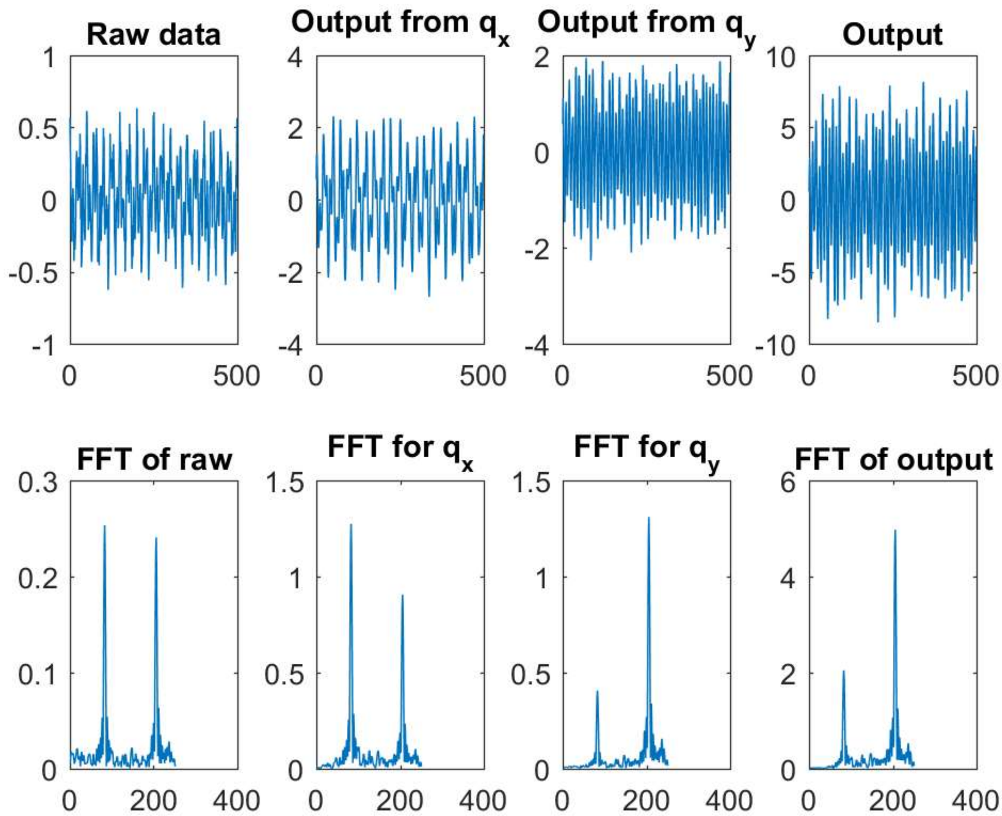

Pole-zero plot for H_x
Imaginary Part
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.5
0
0.5
1
Real Part



Frequency response H_y
Magnitude (dB)
Normalized Frequency (×π rad/sample)
Phase (degrees)
Normalized Frequency (×π rad/sample)



Pole-zero plot for H_y
Imaginary Part
Real Part



Raw data
Output from q_x
Output from q_y
Output
FFT of raw
FFT for q_x
FFT for q_y
FFT of output