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EXPERIMENT 6. SYSTEM IDENTIFICATION WITH ADAPTIVE PROCESSING, DESIGN AND IMPLEMENTATION OF LMS FILTER

PART 2

LABORATORY REPORT

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System Identification

a) Put a screenshot of block diagram for LMS.vi.

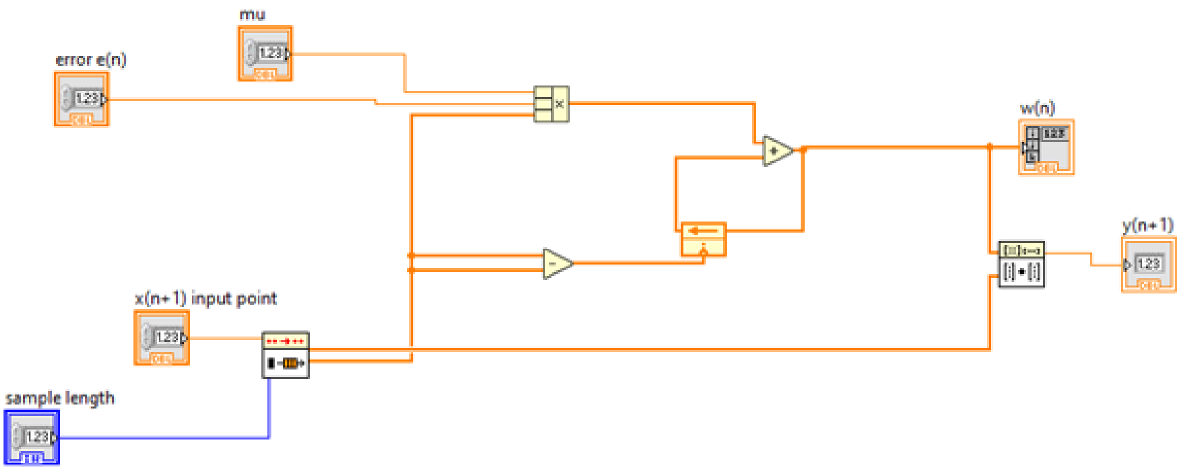

Figure 1: Block diagram of LMS

b) Put a screenshot of the front panel for system identification.

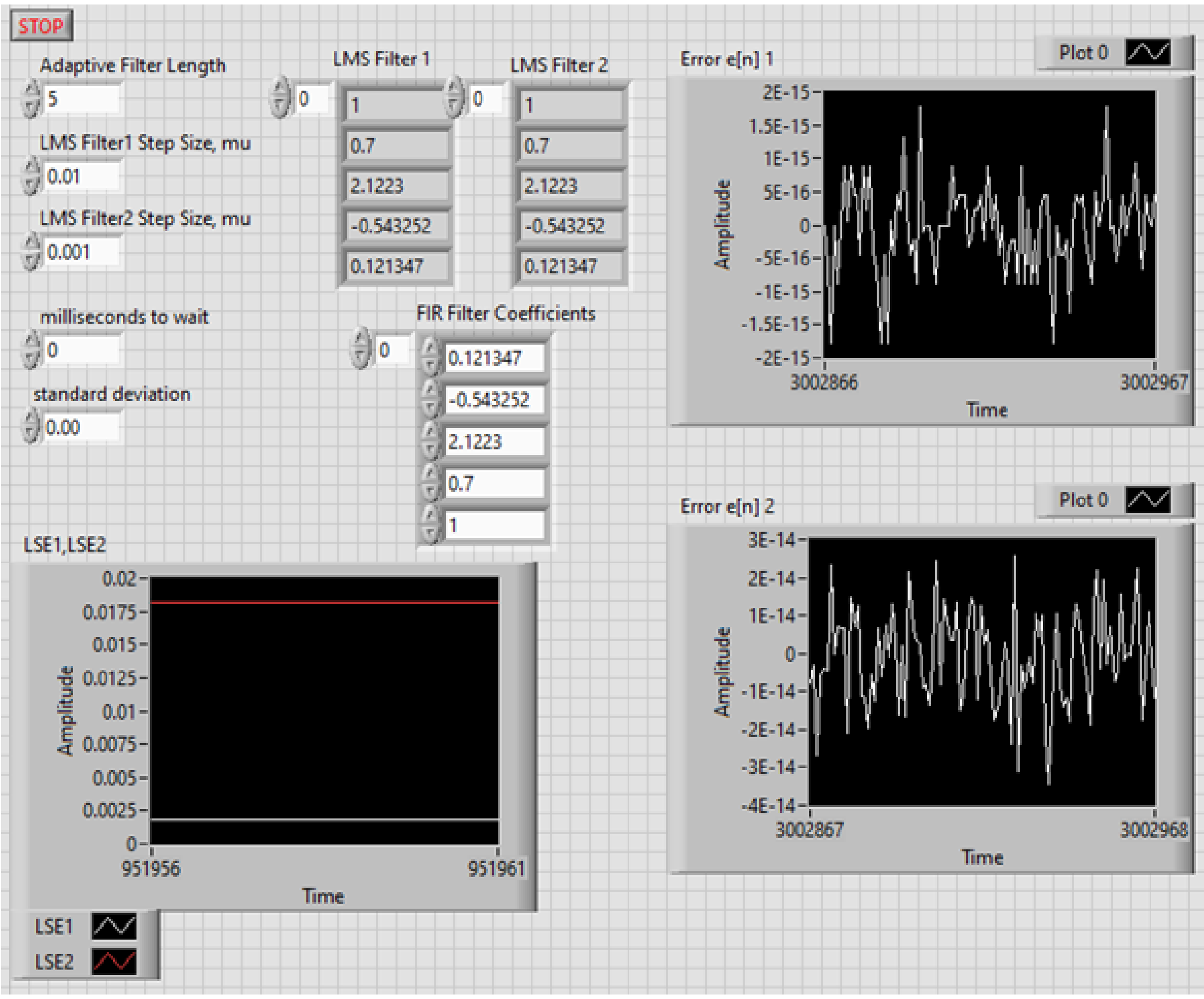

Figure 2: Front panel for system identification

c) Put a screenshot of the block diagram panel for system identification.

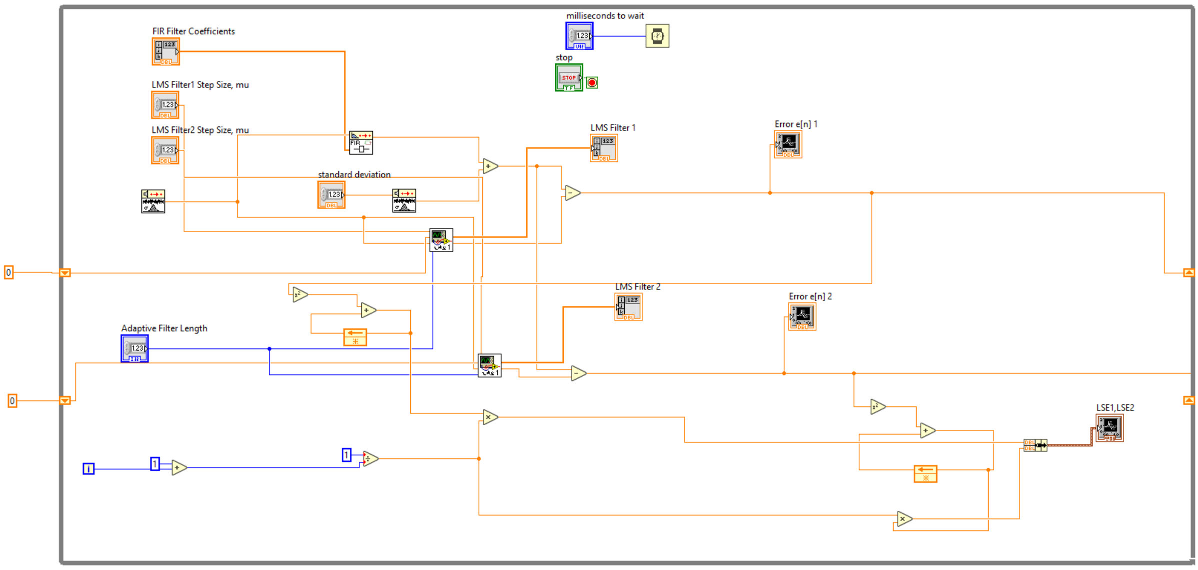

Figure 3: Block diagram panel for system identification

d) Arrange your front panel as given in Experiment Manual Fig.5. Set the noise standard deviation to zero and run the VI. Check if the FIR filter coefficients are found accurately by the adaptive filter. Note that the coefficients should be the same only their order is different. Take a ***screenshot of the Front Panel after convergence***. Set the step sizes for adaptive filters to **0.01** and **0.001** in order to observe the difference between convergence speeds as well as the misadjustments. **Explain** which filter has faster convergence and which filter has the smaller misadjustment.

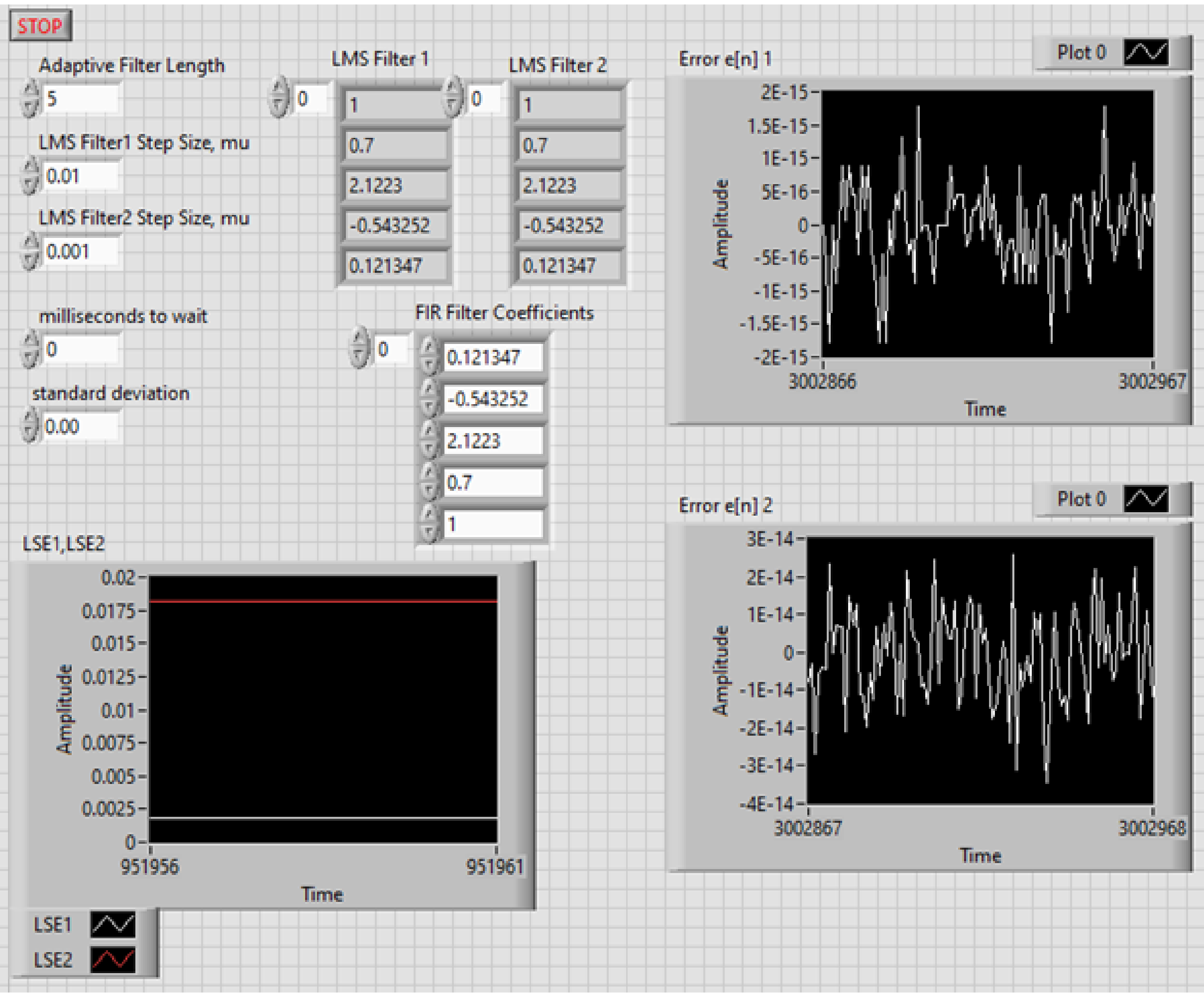

Figure 4: Convergence and misadjustment experiment where M=5, $\mu 1 = 0.01$, $\mu 2 = 0.001$, $\sigma_v = 0$

Convergence speed increases when we increase the step size. We obtain the gradient of the error and by moving in the opposite direction to the gradient, we eventually reach the minimum point. This is called gradient descent. When our step size is small, it takes more time to reach the minimum point. Hence, the convergence speed decreases when we decrease the step size as can be seen in Figure 4, which was expected.

For the misadjustment, since the step size gets smaller, adjustment is finer. Thus, with decreasing step size, misadjustment also decreases. In our experiment, there is no misadjustment observed in both cases, since the noise standard deviation is zero and the step sizes are small enough, which can be again observed from Figure 4.

e) Set the noise standard deviation to 1 and **repeat d**. Wait for approximately two minutes until you do not observe a significant change in the LSE plots. ***Don't forget*** to include the ***screenshot of the Front Panel after convergence***. **Explain** your results and observations.

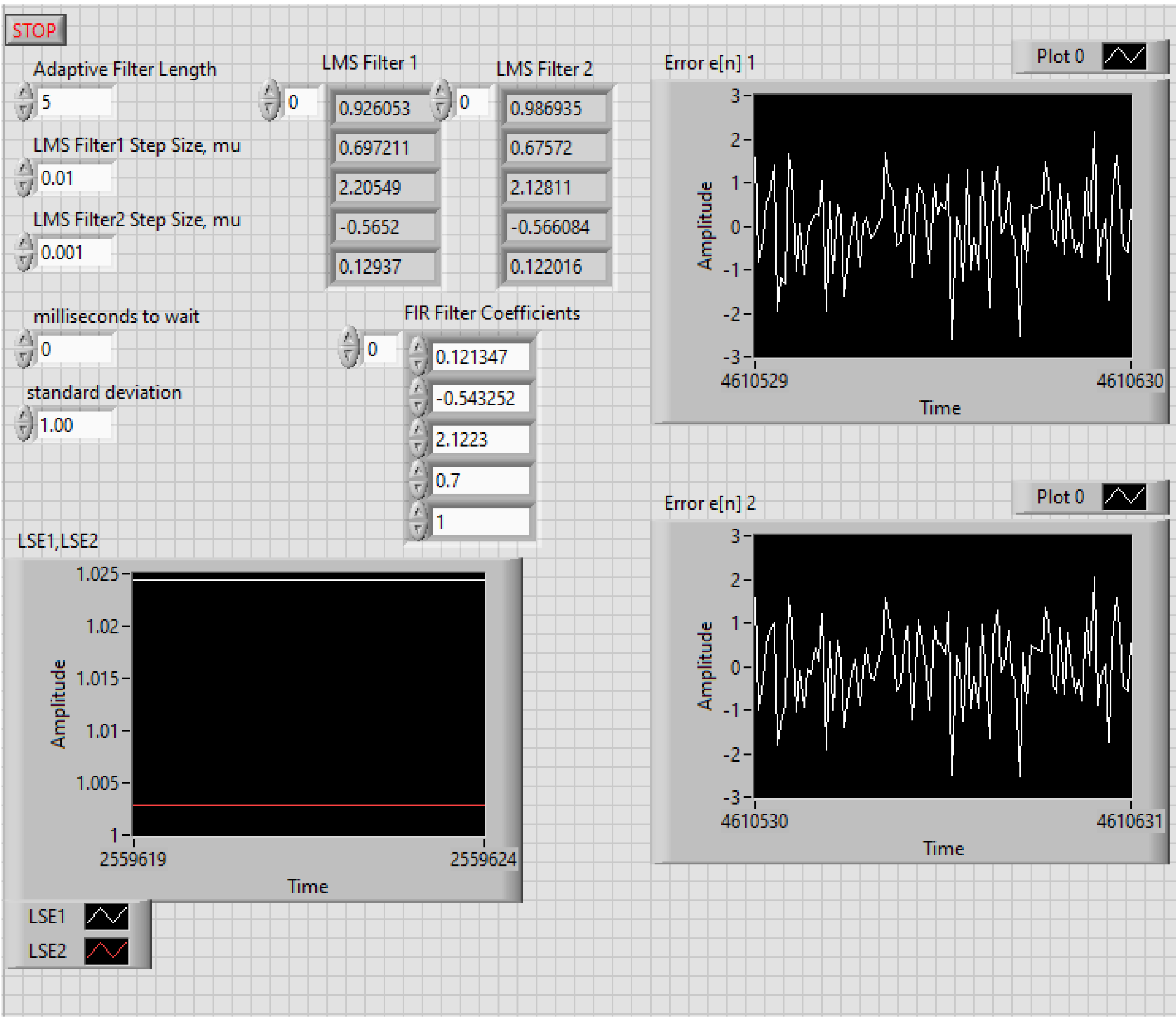

Figure 5: Convergence and misadjustment experiment where M=5, μ1 =0.01, μ2 =0.001, σ_v=1

Convergence rate is similar, however, in this case, we have AWGN in our signal. As our filter has a finite number of coefficients it is impossible to filter all of the noise. We expect to converge to a minimum point using gradient descent with our adaptive filter. However, it is not possible to reach the minimum point with gradient descent; the results will oscillate around it after some point. So, a misadjustment is observed as seen in Figure 5. As stated earlier, "For the misadjustment, since the step size gets smaller, adjustment is finer. Thus, with decreasing step size, misadjustment also decreases." This phenomenon is observed when the step size is decreased, i.e. LSE2 < LSE1.

f) Set the noise standard deviation to 1. Increase the number of coefficients for the first adaptive filter to 10. What is the effect of this? Attach your front panel and write the filter coefficients. **Explain your results.**

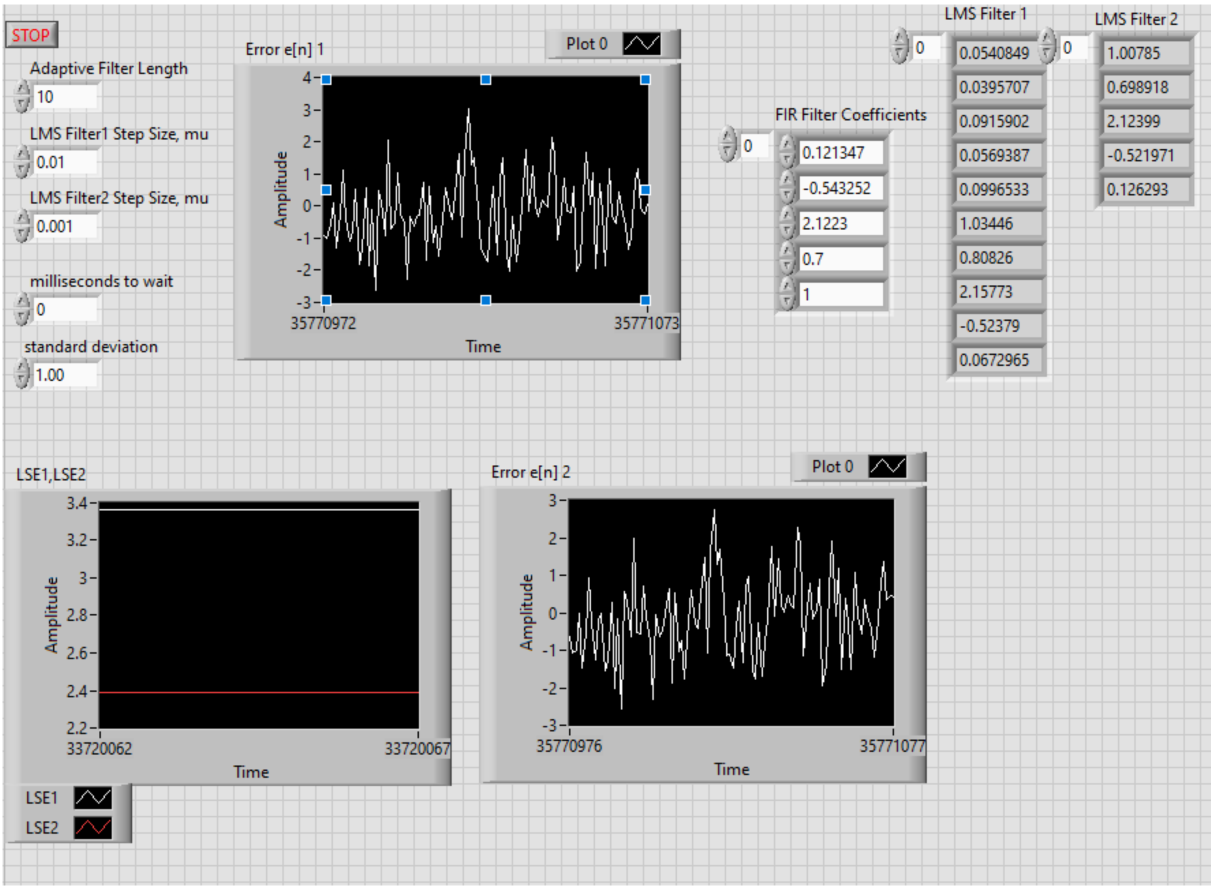

Figure 6: Convergence and misadjustment experiment where M=10, µ1 =0.01, µ2 =0.001, σ_v=1

We set the filter length equal to 10. Our target filter is a 4th order filter and now we are using more than necessary coefficients to replicate the response of the filter. In our experiment, we see that filter coefficients at k=0 to k=4 are approximately the same with the unknown filter, and coefficients with k=5 to k=9 came out as nearly 0. It is not exact, as there is a presence of the noise. Hence, it is not necessary to use a higher order filter.

g) Set the noise standard deviation to 1. Decrease the number of coefficients for the first adaptive filter to 4. What is the effect of this? Attach your front panel and write the filter coefficients. **Explain your results.**

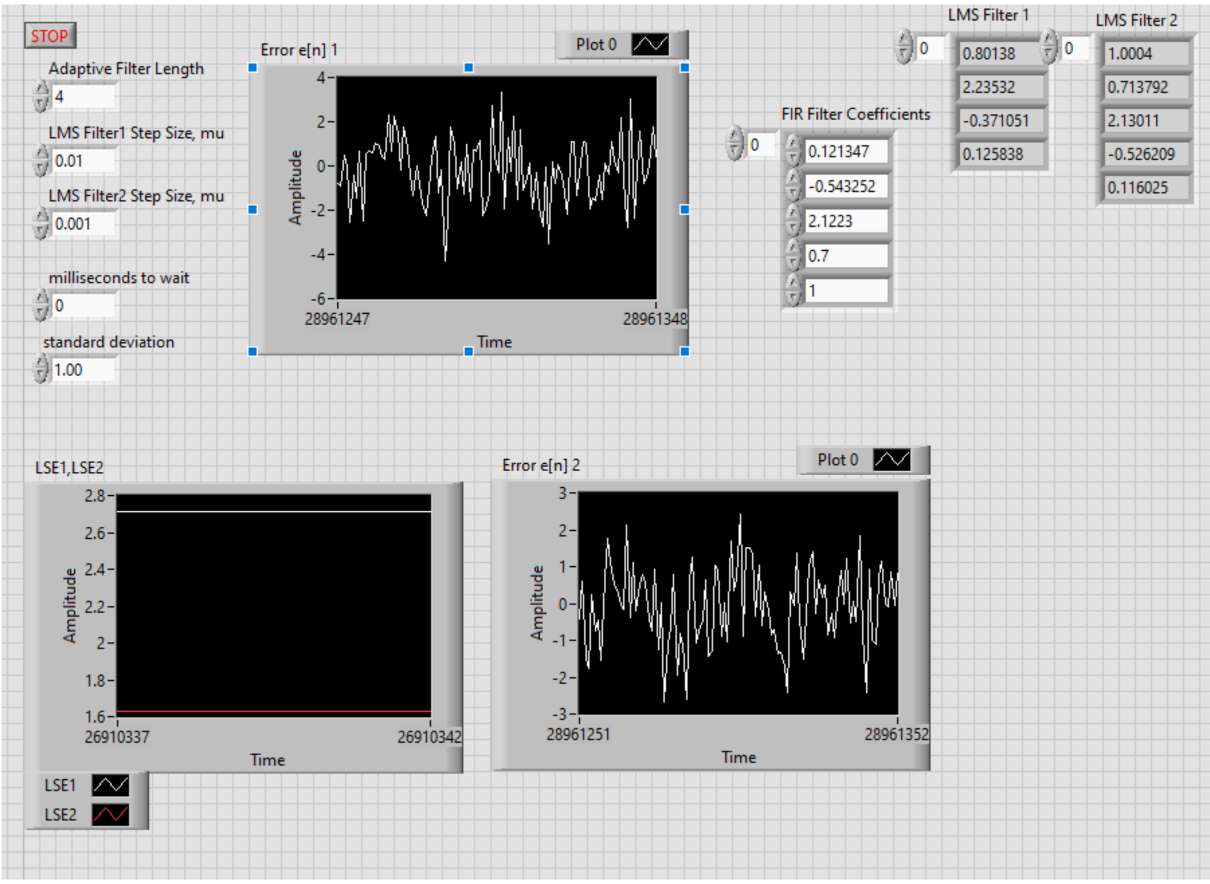

Figure 7: Convergence and misadjustment experiment where M=4, μ1 =0.01, μ2 =0.001, σ_v=1

When we decrease the number of filter coefficients, we try to simulate the frequency response of a 5 point filter with a 4 point filter. First, 4 coefficients are not the same as the unknown filter coefficients because our representation capacity is not enough for reaching the solution. We see the effect of higher order terms, in this case it is 5th, as well as the noise in the first 4 coefficients.

6.6.2. Noise Cancellation

We expect adaptive filter coefficients to converge to the channel filter coefficients. Because input is noise and we define our cost function as the difference between channel filter output added to signal and adaptive filter output. As our adaptive filter does not get any information about the x[n] at its input we expect y[n] to converge to s[n] and hence, the error approaches to x[n].

a) Put a screenshot of the front panel for noise cancellation.

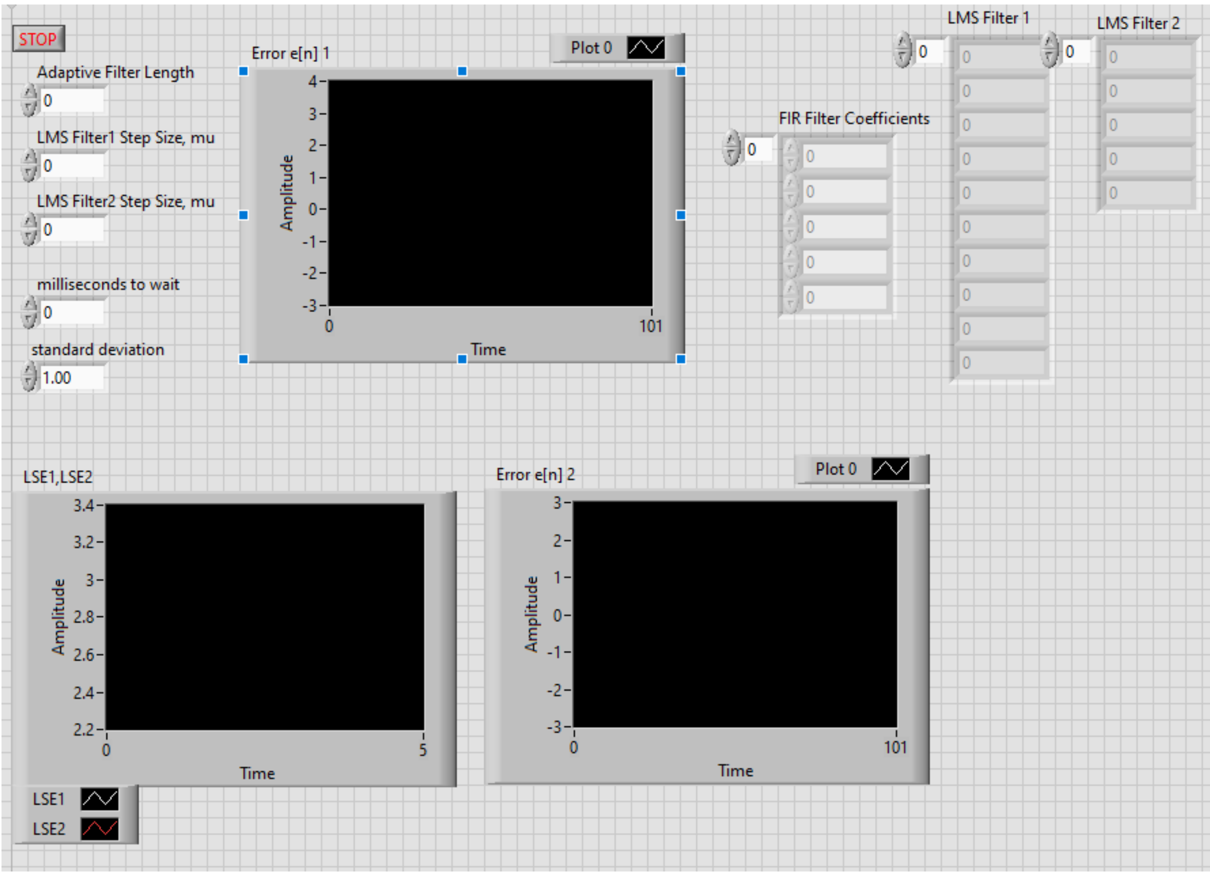

Figure 8: Front panel for noise cancellation

b) Put a screenshot of the block diagram panel for noise cancellation.

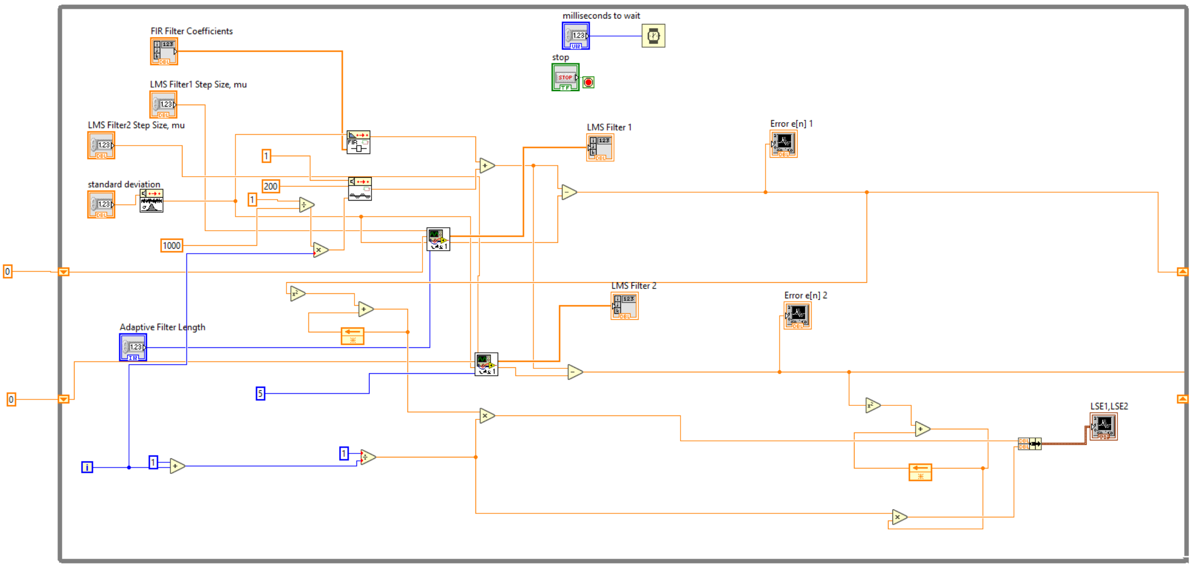

Figure 9: Block diagram panel for noise cancellation

c) Set the noise standard deviation to 1, and step sizes to 0.01 and 0.001. Observe the outputs. Take a ***screenshot of the Front Panel after convergence.*** **Explain** your results.

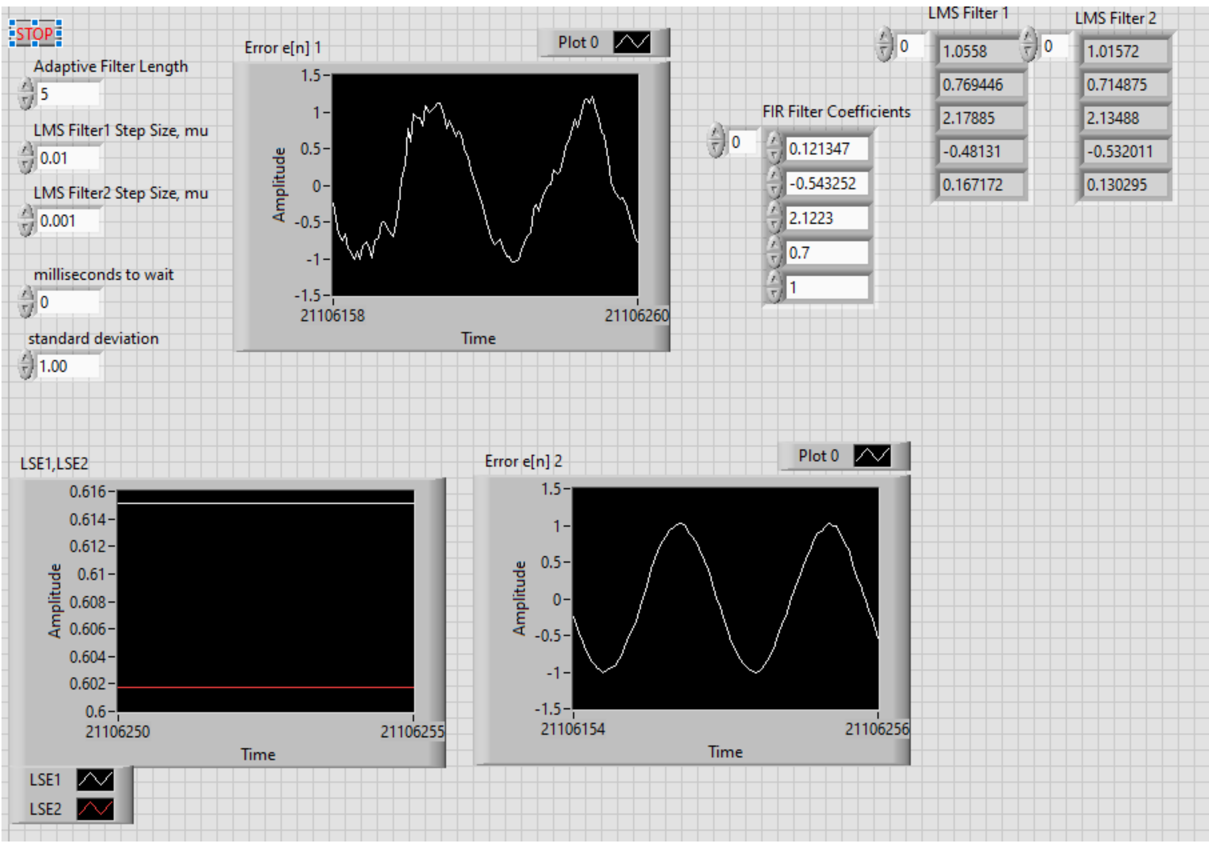

Figure 10: Convergence and misadjustment experiment where M=5, μ1 =0.01, μ2 =0.001, σ_v=1

As in the case of system identification,

- **When our step size is small, it takes more time to reach the convergence. Hence, the convergence speed decreases when we decrease the step size.**
- **For the misadjustment, which only exists in noisy experiments, when the step size gets smaller, adjustment is finer. Thus, with decreasing step size, misadjustment also decreases.**

Both are observed in noise cancellation experiments and seen in Figure 10. Misadjustment can be seen from the form of the sinusoids.

d) Change the noise standard deviation to 2, and repeat part c. Take a ***screenshot of the Front Panel after convergence.*** **Compare them with c. Explain** your results.

$$h_k[n+1] = h_k[n] + \mu e[n] x[n-k], \quad k = 0,1,\ldots,M-1 \qquad \textbf{(1)}$$

As we try to estimate filter coefficients, we multiply step size with the error and x[n-k], which is v[n-k] for noise cancellation as seen from Equation 1. There are two effects playing a role in the rate of convergence, one is the error and the other is the input. As the error is decreasing constantly, the main effect for convergence rate is the input of the adaptive filter, which is the noise and its power.

When we increase the noise standard deviation, the noise power increases. The increase of the power increases convergence rate according to Equation 1, because, to increase the power of noise we just simply multiply the noise with standard deviation, which in this case is 2, so we end up with an equivalent system of doubled step size and unit variance. Thus, the convergence rate and misadjustment is increased.

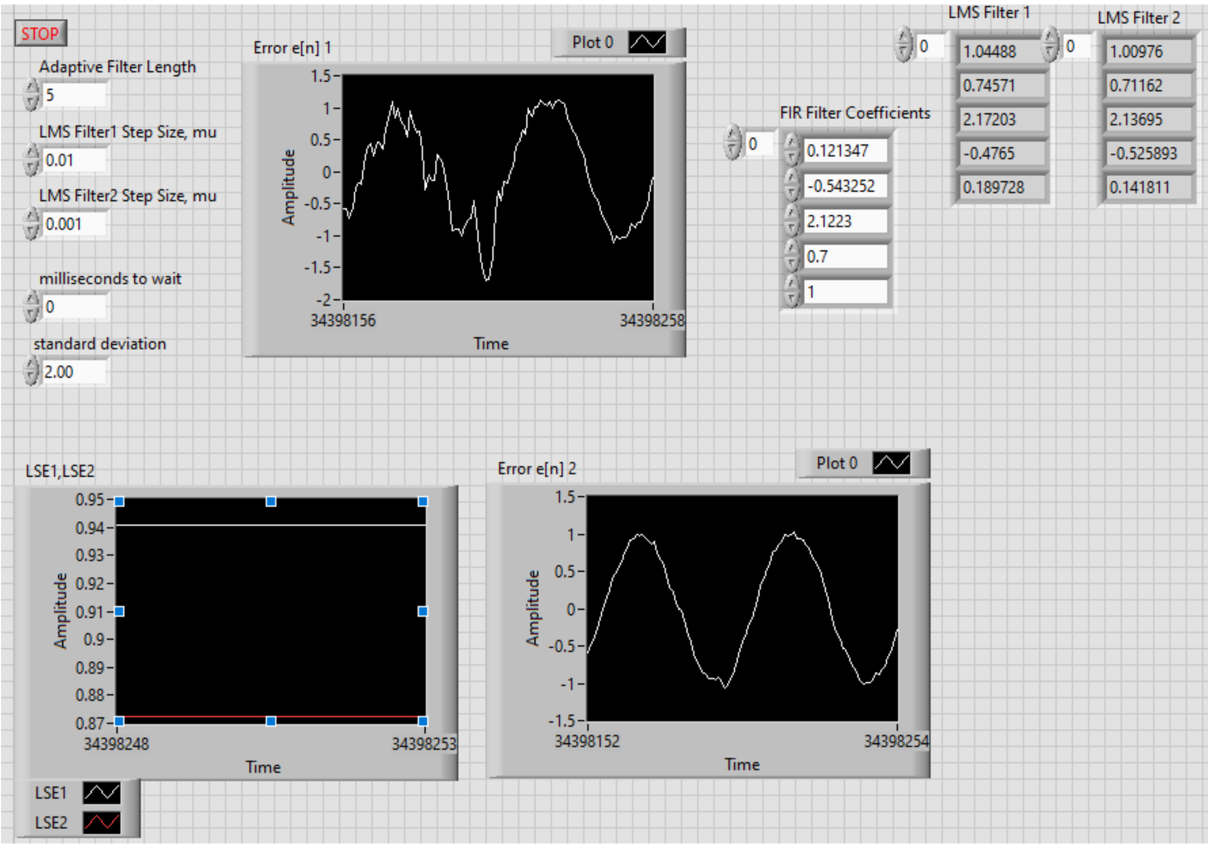

Figure 11: Convergence and misadjustment experiment where M=5, µ1 =0.01, µ2 =0.001, σ_v=2

e) Set noise standard deviation to 1. Increase the number of coefficients for the first adaptive filter to 10. What is the effect of this on noise cancellation? Attach your front panel and write the filter coefficients. **Explain your results.**

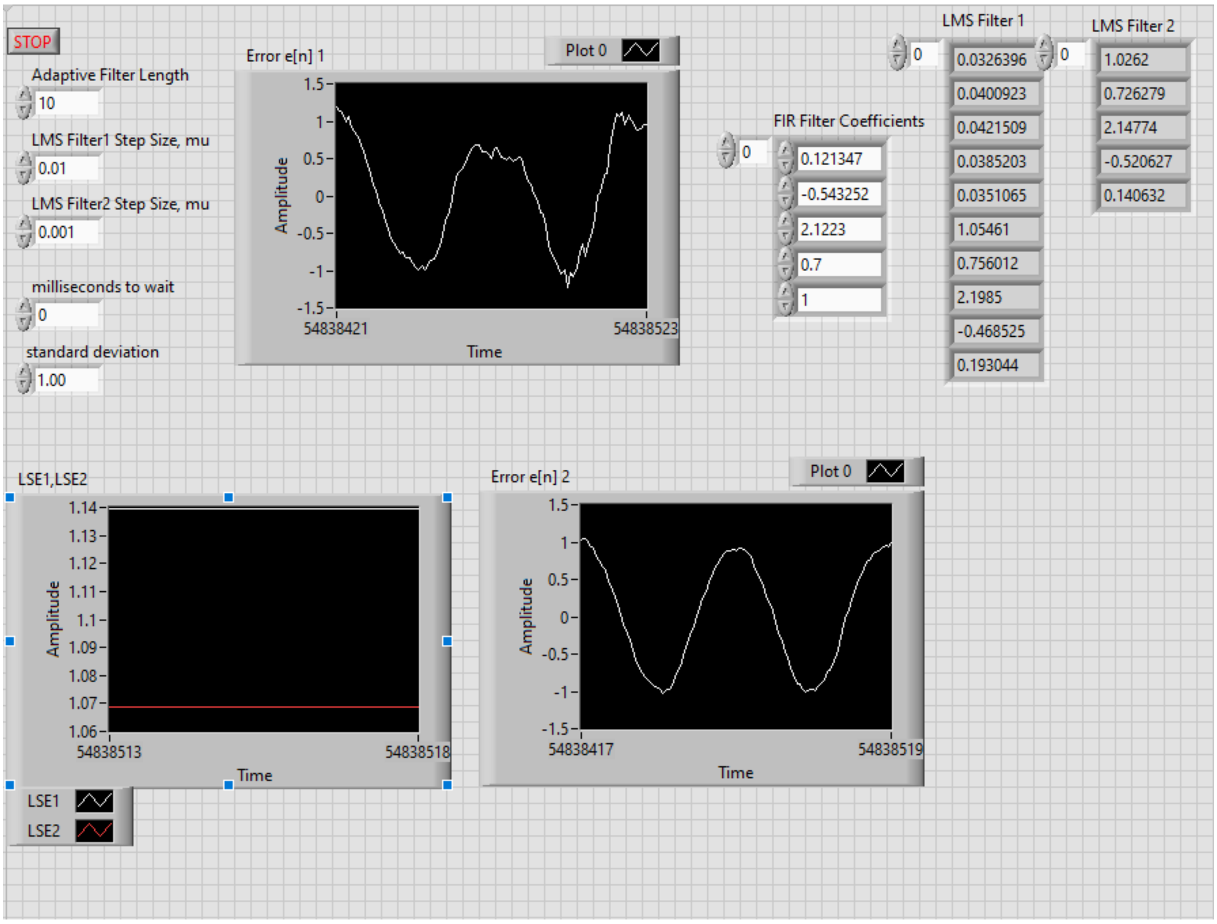

Figure 12: Convergence and misadjustment experiment where M=10, μ1 =0.01, μ2 =0.001, σ_v=1

We set the filter length equal to 10. Our target filter is a 4th order filter and now we are using more than necessary coefficients to replicate the response of the filter. In our experiment, we see that filter coefficients at k=0 to k=4 are approximately the same with the unknown filter, and coefficients with k=5 to k=9 came out as nearly 0. It is not exact, as there is a presence of the noise. Hence, it is not necessary to use a higher order filter.

f) Decrease the number of coefficients for the first adaptive filter to 4. What is the effect of this on noise cancellation? Attach your front panel and write the filter coefficients. **Explain your results.**

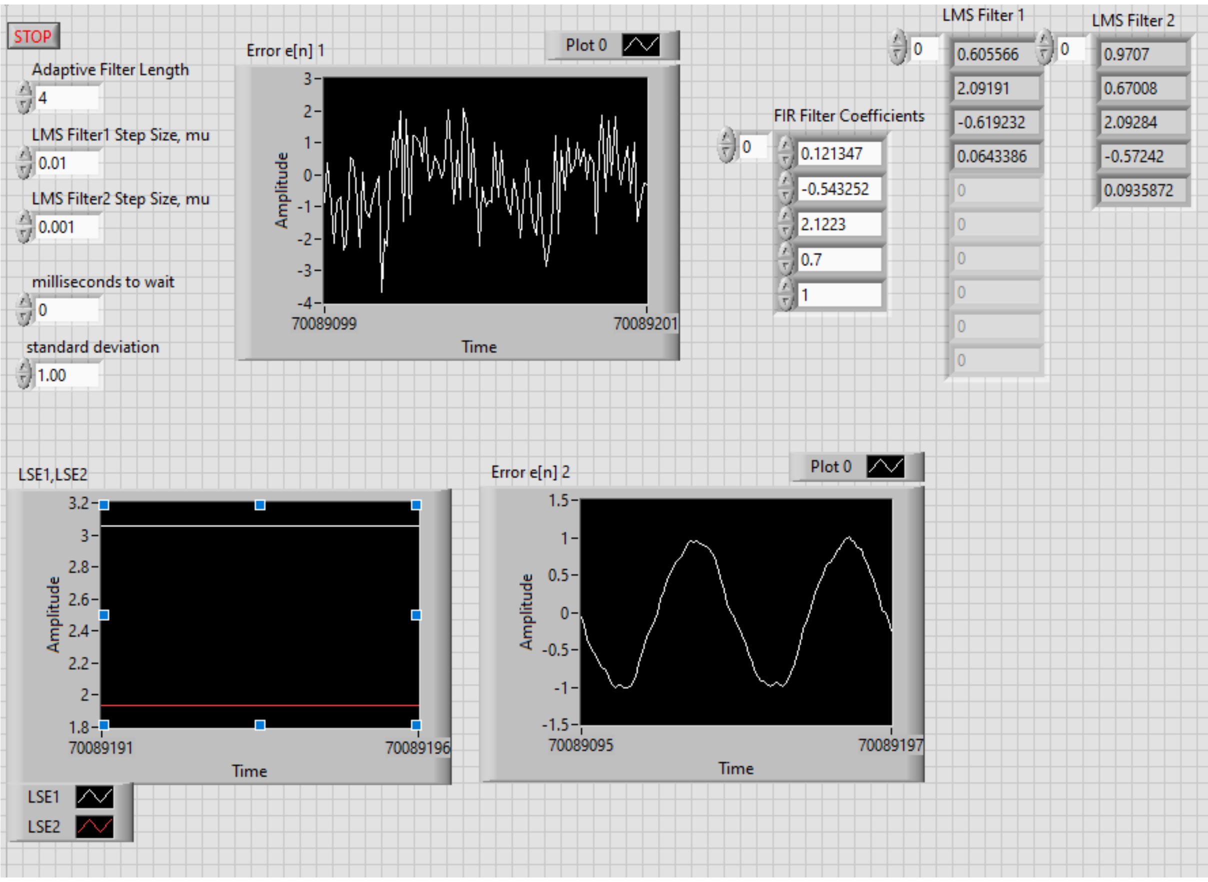

Figure 13: Convergence and misadjustment experiment where M=4, μ1 =0.01, μ2 =0.001, σ_v=1

When we decrease the number of filter coefficients, we try to simulate the frequency response of a 5 point filter with a 4 point filter. First, 4 coefficients are not the same as the unknown filter coefficients because our representation capacity is not enough for reaching the solution. We see the effect of higher order terms, in this case it is 5th, as well as the noise in the first 4 coefficients.