ELEC-E8101 Group project: Lab C report Group 05

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Reporting of Task 6.1

6.1.1: The best sampling frequency for this lab was found to be 40 Hz

But when we tried doing the experiments on the last task. i.e testing with different signals, we had to make it to 60 Hz. Because with the Reference signal we found out that 60Hz the robot was little bit smooth. So we wanted to choose the best sampling frequency for the lab C as 60Hz

6.1.2: The corresponding values of system Matrices are:

$$A_d = \begin{bmatrix} 1.0000 & 0.0033 & -0.0000 & 0.0003 \\ 0 & -0.6105 & -0.0037 & 0.0338 \\ 0 & 0.0588 & 1.0052 & 0.0158 \\ 0 & 6.9132 & 0.6109 & 0.8600 \end{bmatrix}$$

$$B_d = \begin{bmatrix} 0.0006 \\ 0.0762 \\ -0.0028 \\ -0.3270 \end{bmatrix}$$

$$C_d = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

$$D_d = 0$$

Reporting of Task 6.2

6.2.1: The choice of $\bar{C}$ was

$$\begin{bmatrix} 11 & 5 & 10 & 1 \end{bmatrix}$$

and value of ρ we choose here is 0.1

The reason for this $\bar{C}$ is that we need to penalize more for θ_b

The following analysis were made:

1. If the $\dot{\theta}_b$ is penalized more, then the overshoot increases.
2. If the θ_b is penalized, the robot stabilizes well within approximately 1.5s and the

undershoot is less.So we prefer to penalize this more. This penalizing brings us a little bit better performance from LabB.
3. Also we need to penalize the x_w and $\dot{x_w}$ of the system to give more penalty for constant movement of the robot. We don't want the robot to keep moving which will cause unnecessary changes in value of θ_b

Now for the value of ρ, it is this value, for which we had the poles and zeros in SRL plot which looks similar

6.2.2: The SRL plot for the system is given by (in Figure 1)

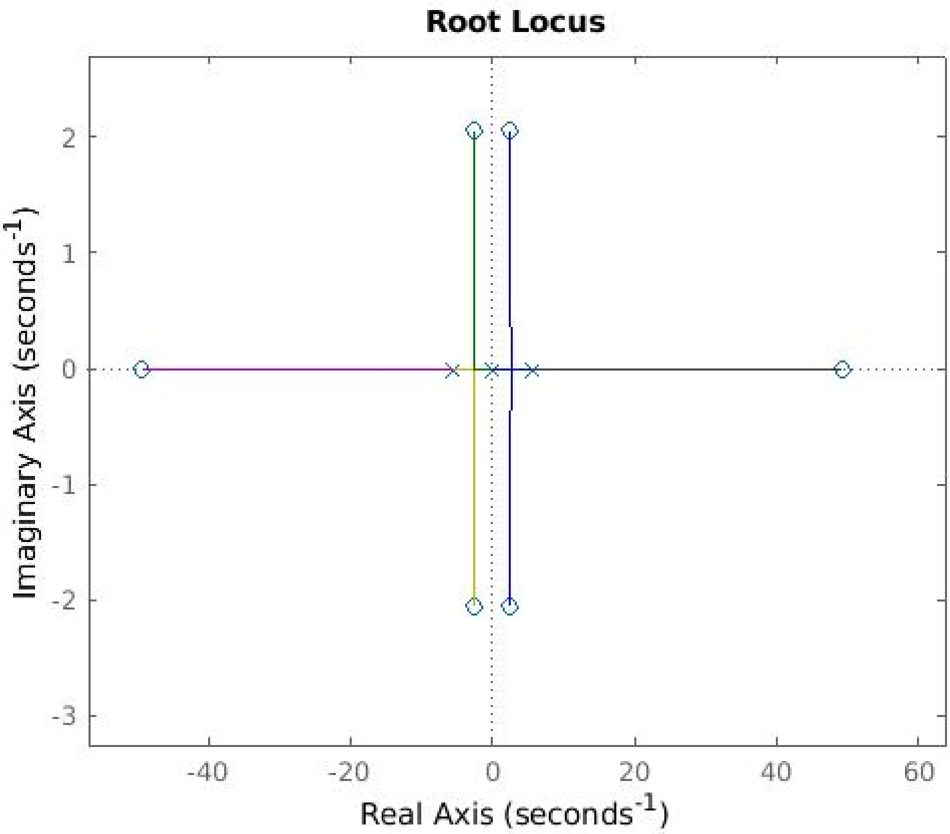

Figure 1: SRL for the system

To compute the SRL, we first took the system transfer function $G(S)$, then we had to substitute $G(-s)$ and we had to multiply $H(S) = G(s) * G(-s)$. Then the Matlab function $rlocus(H(s))$ is computed.

6.2.3: The value of K is

$$K_d = \begin{bmatrix} -34.7851 & -54.7957 & -83.0831 & -12.9110 \end{bmatrix}$$

we computed this using the inbuilt matlab function $lqr()$

$$K_d = lqr(robot, \bar{C}' * \bar{C}, row)$$

6.2.4: The plots of θ_b and v_m are found in Figure 2 and Figure 3

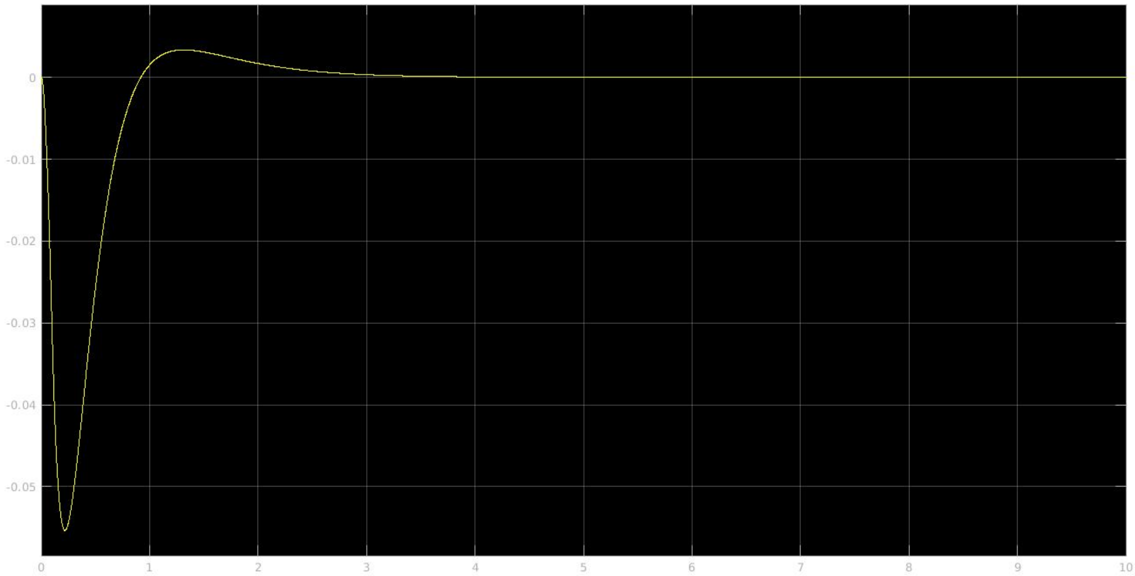

Figure 2: θ_b for the system

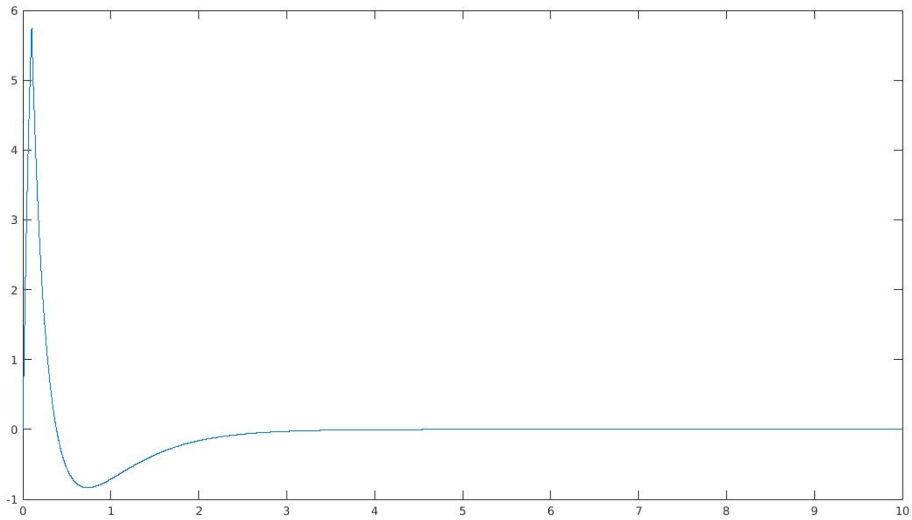

Figure 3: v_m for the system

6.2.5: For the forthcoming experiments, it is advisable to have the LQR based pole placement methods, because the performance looks better in the simulation, also here we find that the deviation of θ_b is less and the input required has less undershoot.

Reporting of Task 6.3

6.3.1: The sampling frequency for which the robot falls is 4.2Hz for continous time system and the Corresponding sampling period is 0.232s.

6.3.2: The values of system matrices are

$$A_d = \begin{bmatrix} 1.0000 & 0.0414 & 0.0382 & 0.0092 \\ 0 & -0.6691 & 0.3056 & 0.0733 \\ 0 & 1.9664 & 3.0424 & 0.4640 \\ 0 & 15.7316 & 16.3389 & 2.7120 \end{bmatrix}$$

$$B_d = \begin{bmatrix} 0.0099 \\ 0.0789 \\ -0.0930 \\ -0.7441 \end{bmatrix}$$

$$C_d = \begin{bmatrix} 1.0000 & 23.7835 & 32.6802 & 5.6092 \end{bmatrix}$$

$$D_d = -1.0717$$

and the value of K_d is

$$K_d = \begin{bmatrix} -4.7274 & -26.4190 & -38.1397 & -6.1512 \end{bmatrix}$$

Reporting of Task 6.4

6.4.1: The sampling frequency for which we lose the stability with full observer in the simulator is 20Hz (Sampling Period= 0.05)

Also, we tested with the reduced order observer, the sampling frequency for which we lose the stability with reduced order observer is 18Hz (Sampling Period = 0.055)

6.4.2: The critical Sampling frequency is now different because(but seem to be no much difference), we introduced the observer in this part which is also discretized. This introduction of observer will have the effect of delay in the system,because so many components are added to the current system ,this causes robot to be unstable in 20Hz. We only had controller in the previous experiment, but now we have the observer integated to the system.

6.4.3: The values of the Observer and Controllers are

$$K_d = \begin{bmatrix} -17.0848 & -38.5595 & -56.0526 & -8.8761 \end{bmatrix}$$

$$L_d = \begin{bmatrix} 0.3363 & 0.1123 \\ 166.0689 & -57.1009 \\ 2.2384 & 0.9028 \\ -701.2788 & 252.2250 \end{bmatrix}$$

$$M_{d1} = \begin{bmatrix} -0.7694 & -0.2461 & 0.0415 \\ 0.3676 & -0.1652 & 0.0887 \\ 8.1180 & -3.6219 & 0.9557 \end{bmatrix}$$

$$M_{d2} = \begin{bmatrix} 0.0883 \\ -0.0201 \\ -0.4261 \end{bmatrix}$$

$$M_{d3} = \begin{bmatrix} 1.0706 \\ -0.6222 \\ -9.8023 \end{bmatrix}$$

$$M_{d4} = \begin{bmatrix} 0.2961 \\ 1.3097 \\ 6.8062 \end{bmatrix}$$

$$M_{d5} = \begin{bmatrix} -1.0706 \\ 0.6222 \\ 9.8023 \end{bmatrix}$$

$$M_{d6} = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$M_{d7} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The System matrices are

$$A_d = \begin{bmatrix} 1.0000 & 0.0100 & 0.0022 & 0.0018 \\ 0 & -0.7801 & 0.0477 & 0.0396 \\ 0 & 0.3738 & 1.1459 & 0.0898 \\ 0 & 8.2161 & 3.2056 & 0.9733 \end{bmatrix}$$

$$B_d = \begin{bmatrix} 0.0038 \\ 0.0842 \\ -0.0177 \\ -0.3886 \end{bmatrix}$$

$$C_d = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

$$D_d = 0$$

Reporting of Task 6.5

6.5.1: The first sampling frequency for which our robot balances is 40Hz(Sampling period = 0.025s)

6.5.2: The L2 norm of the x_w and θ_b for different frequencies is shown below (Figure 4 and Figure 5 respectively). As we can see from the figures, for a change in θ_b we have an act of x_w.

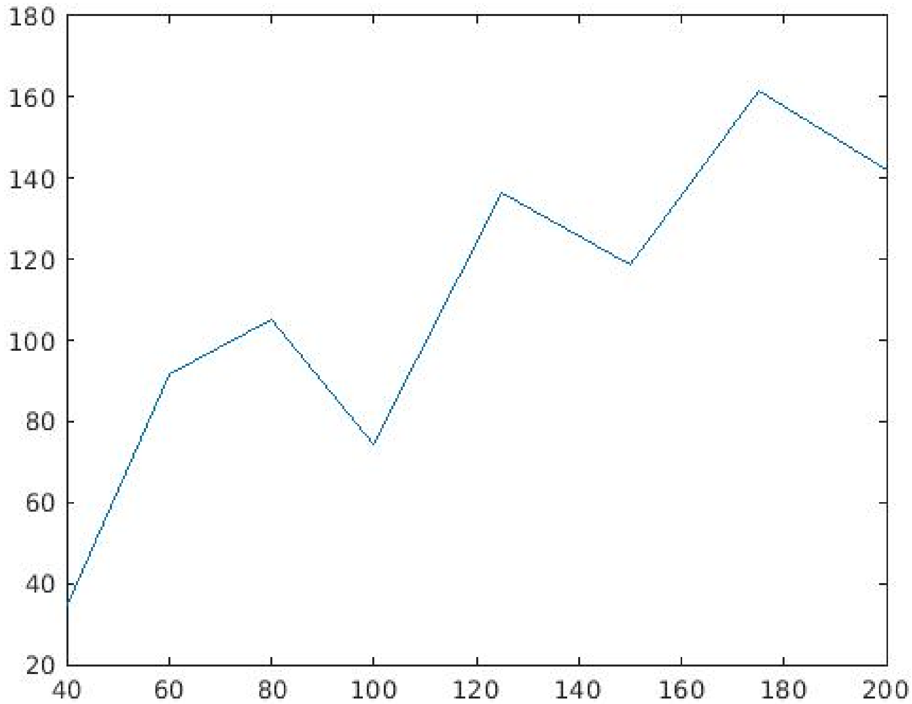

Figure 4: L2 norm of x_w for the system

The range of data for different values of sampling frequencies is given below. (Note : Only some examples are given below - Figure 7- Figure 11)

The individual trail data was recorded and plotted below:

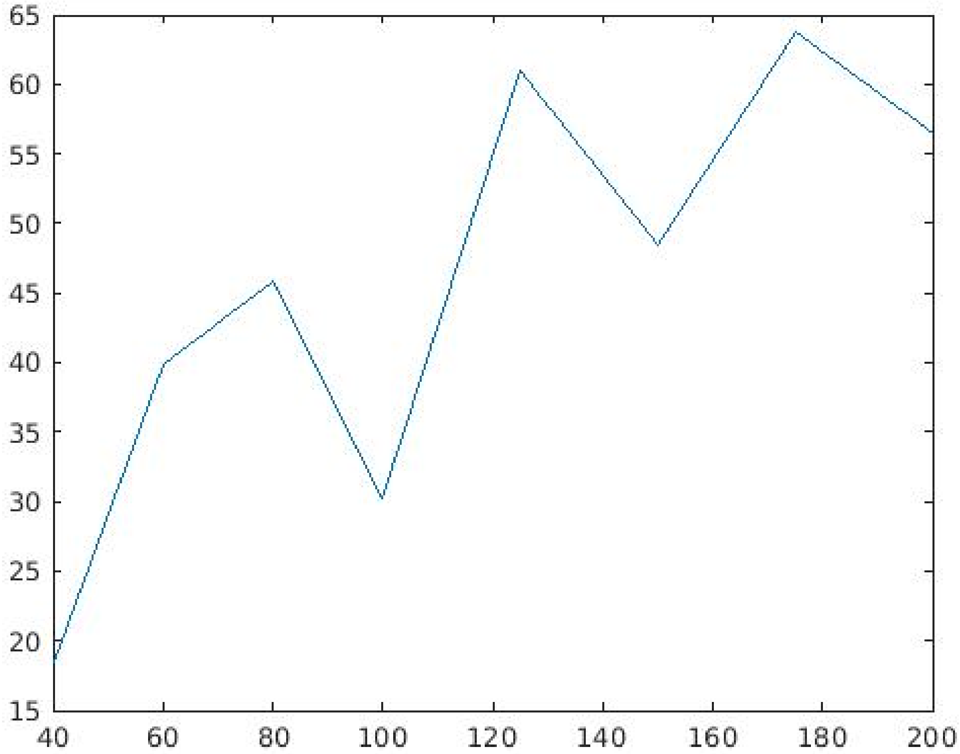

Figure 5: L2 norm of θ_b for the system

SAMPLING FREQUENCY	L2 Norm of x_w	L2 Norm of θ_b
40	34.6106	18.4492
60	91.7958	39.7880
80	105.3245	45.8704
100	74.3463	30.2932
125	136.2936	61.0635
150	118.7225	48.3957
175	161.7415	63.7859
200	141.7694	56.4019

The method used of calculating the L2 Norm was : norm(x_w) ,norm(θ_b) in Matlab

Figure 6: Table of values for different sampling frequencies

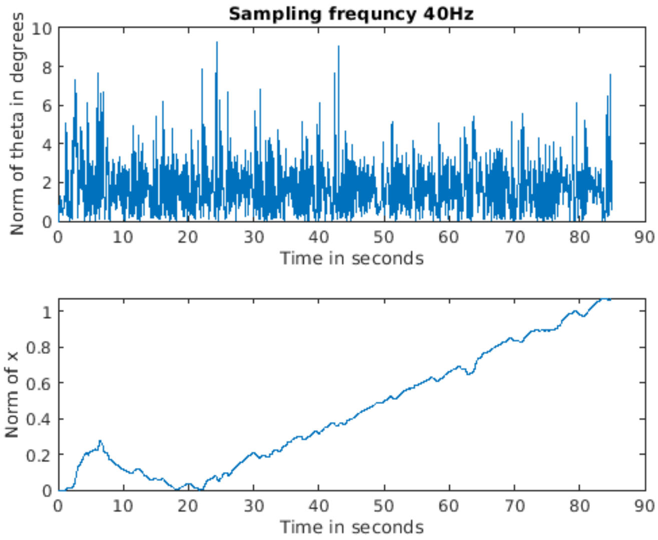

Figure 7: x_w and θ_b for 40Hz

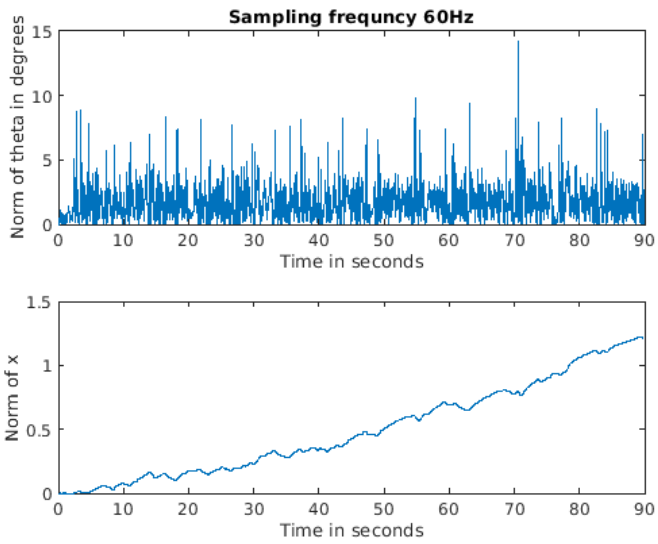

Figure 8: x_w and θ_b for 60Hz

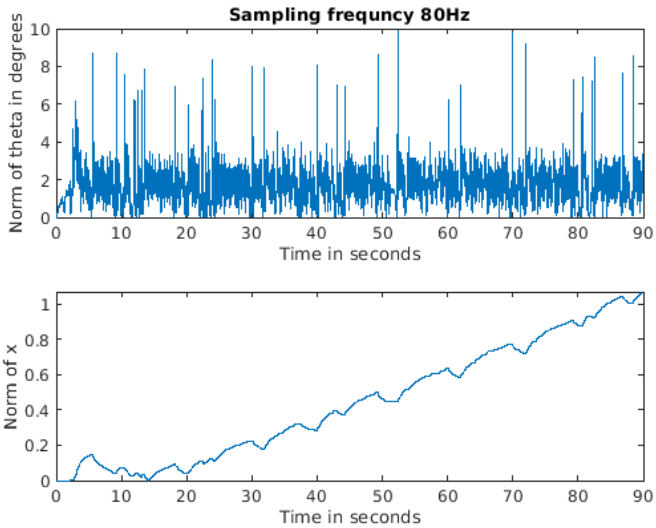

Figure 9: x_w and θ_b for 80Hz

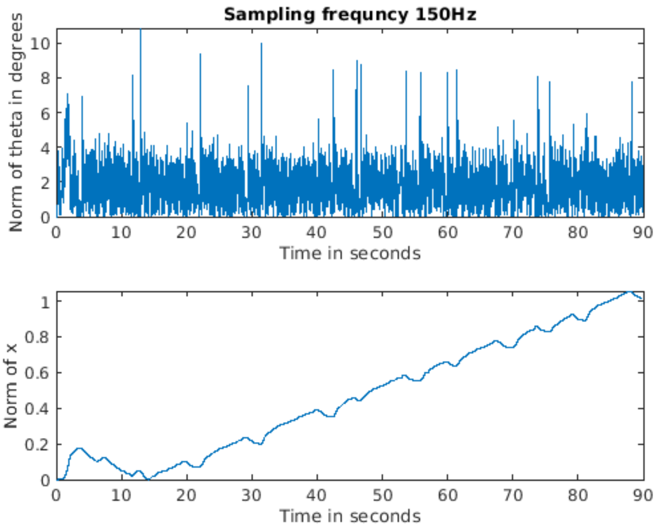

Figure 10: x_w and θ_b for 150Hz

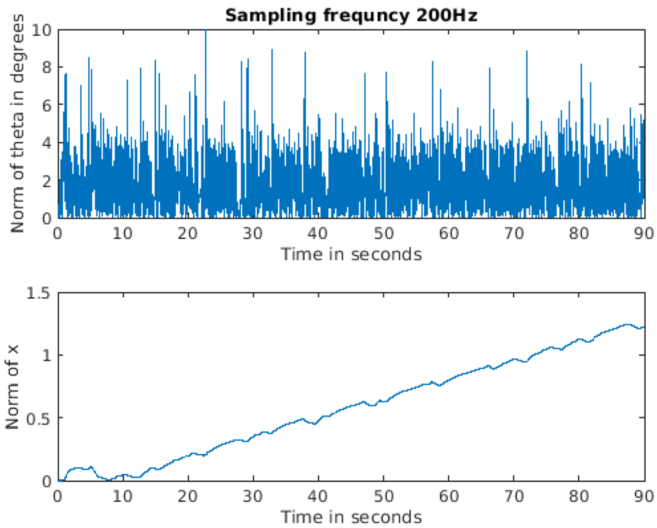

Figure 11: x_w and θ_b for 200Hz

Reporting of Task 6.6

6.6: The formula for computing the N is:

$$F = \begin{bmatrix} A_d - I & B_d \\ C_d & D_d \end{bmatrix}$$

$$N = \begin{bmatrix} Nxd \\ Nud \end{bmatrix}$$

$$N = F^{-1} * \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

6.6.2 :

We tested for few signals and the results are shown below:

Final Report values: We tried for different r_{max} values as mentioned in the labBook Reference signal column, and found out the value of r_{max} for which the maximum value where our Robot didn't fall was

$$r_{max} = 0.1$$

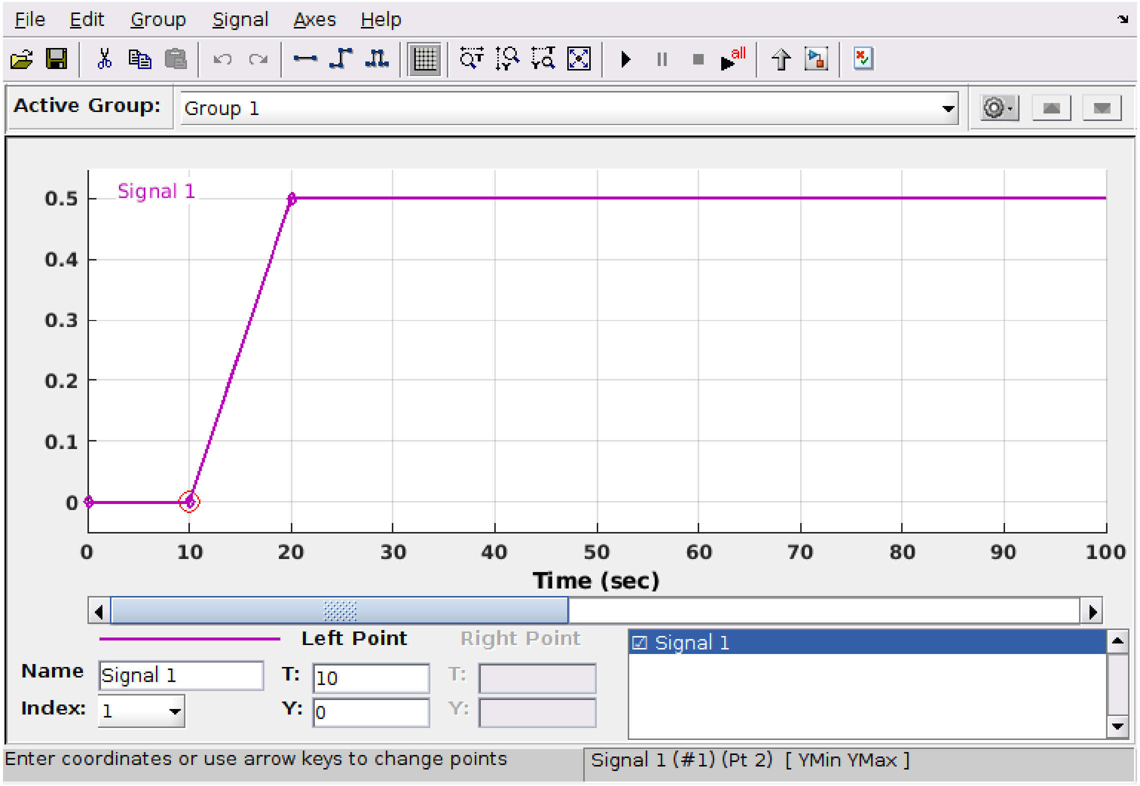

Figure 12: Reference Signal 1

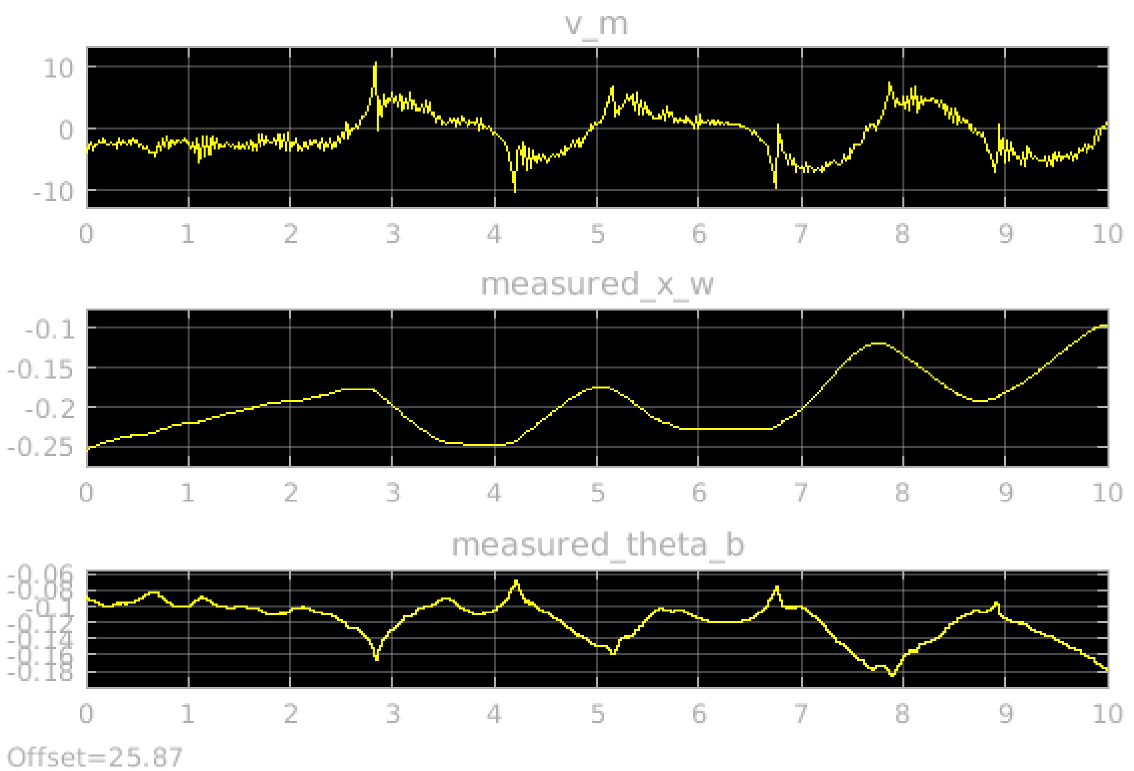

Figure 13: Reference Signal 1 output values

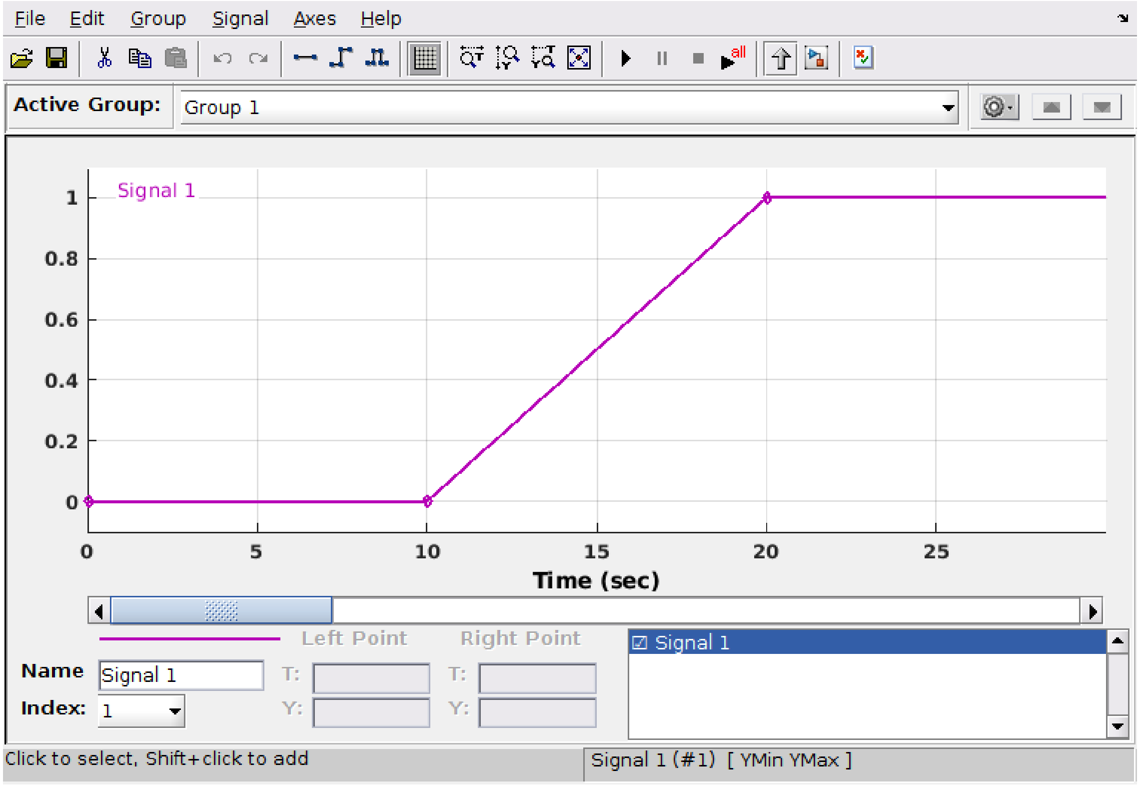

Figure 14: Reference Signal 2

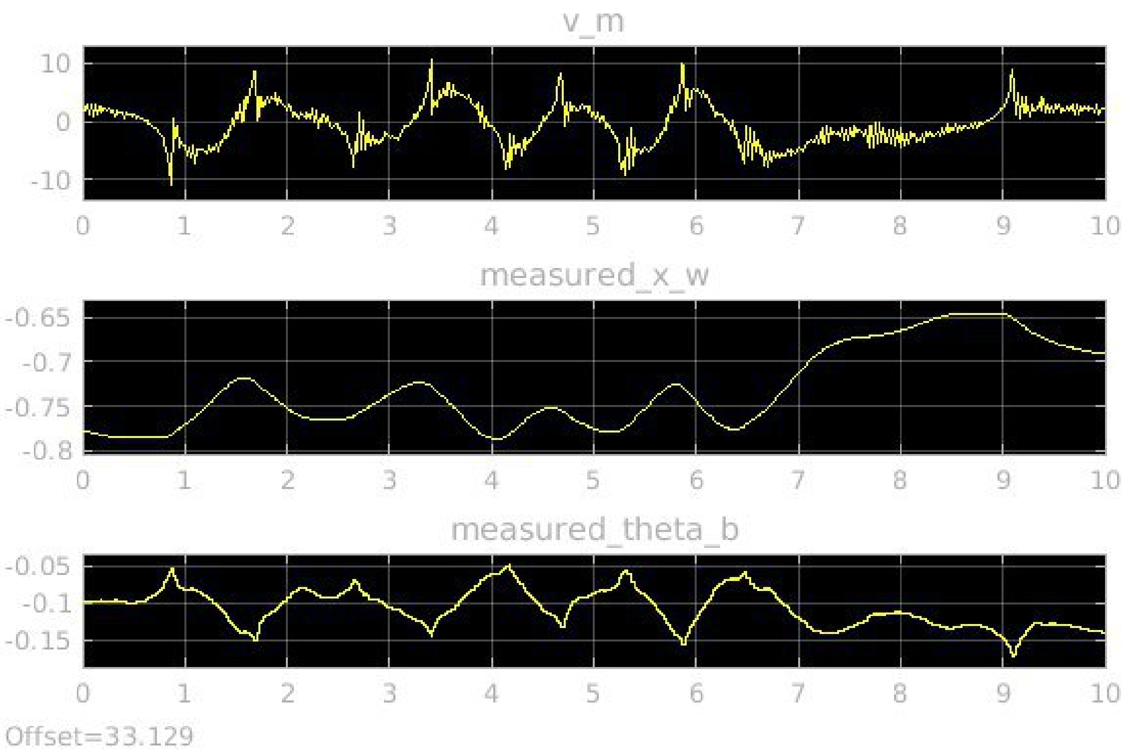

Figure 15: Reference Signal 1 output values