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By filling out the names above, the group members acknowledge that a) they have jointly authored this submission, b) this work represents their original work, c) that they have not been provided with nor examined another person's assignment, either electronically or in hard copy, and d) that this work has not been previously submitted for academic credit.			

LAB 1. INSTRUMENTATION AND MEASUREMENT TECHNIQUES

ASSIGNED DATA

For easily referencing it, the Assigned Data has been placed at the start of this document.

With your pre-lab and post-lab submissions, always include this page at the beginning of your report.

Select your lab session:	☐ morning lab; ☒ afternoon lab; ☒ Tue; ☐ Wed; ☐ Thu
CourseBook Group Number	$GroupNum =$
Assigned bandwidth (open-loop) formula [rad/s]	$GroupNum \times 30 + 350 - rounddown\left(GroupNum / 21.5, 0\right) * 650$ (valid Excel formula syntax; result should be between 300 and 1000)
Assigned bandwidth value (open-loop) [rad/s]	400
Assigned K_p value	3

Bandwidth measuring procedure To measure the bandwidth we first measured the output amplitude at a suitably low frequency (we used 10Hz). From there we calculated what the bandwidth output amplitude should be by dividing the output amplitude at our low frequency by $\sqrt{2}$. After marking this value with a cursor on the graph we altered the input freqency until we reached our calculated output amplitude, this frequency was our bandwidth.

Table 3 Discussion The bandwidth for a open-loop system is much smaller than the bandwidth in a closed-loop system. This is because bandwidth is calculated at the frequency at which the output increases proportionally to the input. In a closed loop system the input also contains the output so these two values are much closer which means the bandwidth much increase more to effect this ratio. Out results support this concept, but there were errors. These could be due to inaccurate graph reading, noise in the system, or mathematical errors when calculating the theoretical values.

Table 4 Discussion The time constant is much smaller for a closed-loop system due to the stabilizing nature of a closed-loop system. Due to the output being fed into the input of the system, a closed loop system reaches its stable output much more quickly resulting in a lower time constant. The input function is now much larger and climbs faster allowing it to reach a portion of the output much faster.

Table 5 Discussion Since settling time is the time it takes to reach a portion of the steady state value of the system, a closed-loop system whose input function is much larger due to the addition of the output function will reach its steady state much faster. This is also due to the input signal of a closed-loop system being very similar to the output signal, allowing them to match quickly.

Clipping Clipping was observed at a value of $K_p = 28$ resulting in a clipped amplitude of 24.78V. This was possibly due to limitations of the signal generator (such as limitations on possible voltage generated) or the signal generation software (overflow errors in the software).

Measurements at low-frequency			Measurements at bandwidth frequency		
Peak-to-peak amplitude of output	**Frequency (Hz)**	**Frequency (rad/s)**	**Peak-to-peak amplitude of output**	**Frequency (Hz)**	**Frequency (rad/s)**
3	10	62.8	2.11	63.69	400

Table 1: Open-loop bandwidth measurements in time domain

Measurements at low-frequency			Measurements at bandwidth frequency		
Peak-to-peak amplitude of output	**Frequency (Hz)**	**Frequency (rad/s)**	**Peak-to-peak amplitude of output**	**Frequency (Hz)**	**Frequency (rad/s)**
0.78	10	62.8	0.55	238.85	1500

Table 2: Closed-loop bandwidth measurements in time domain

Figure 1: Open-loop configuration

Figure 2: Closed-loop configuration

	Bandwidth in time domain	**Bandwidth in freq domain**	**Bandwidth in Matlab**	**Bandwidth theoretical**	**Error Theor Time-Dom (%)**	**Error Theo FreqDom (%)**
Open-loop	63.9	64	65.7	63.69	0.33%	0.49%
Closed-loop	238.85	240	246.3	238.85	0%	0.48%

Table 3: Summary of bandwidth results

	Tau Experimental	**Tau Matlab**	**Tau Theoretical**	**Tau Error Theoretical vs Exerimental (%)**
Open-loop	2.50E-003	2.53E-003	2.50E-003	0%
Closed-loop	675E-006	662E-006	666.67E-006	0.002%

Table 4: Summary of time-constant results

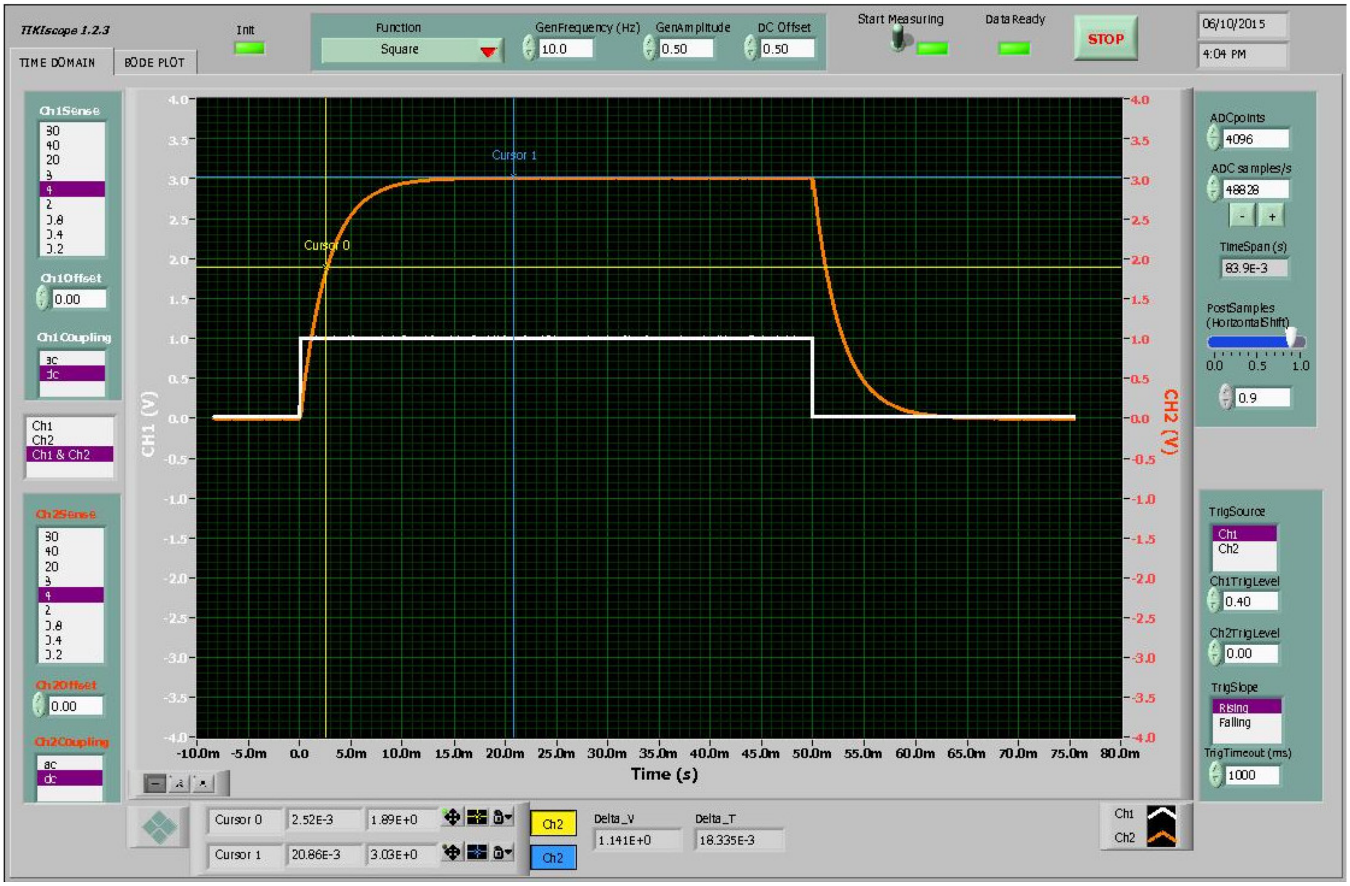

Figure 3: Time constant for open-loop configuration

	Tau Experimental	Tau Matlab	Tau Theoretical	Tau Error Theoretical vs Exerimental (%)
Open-loop	10.00E-003	10.0E-003	9.78E-003	0.22%
Closed-loop	3.00E-003	2.99E-003	2.45E-003	6.3%

Table 5: Summary of 2% settling time results

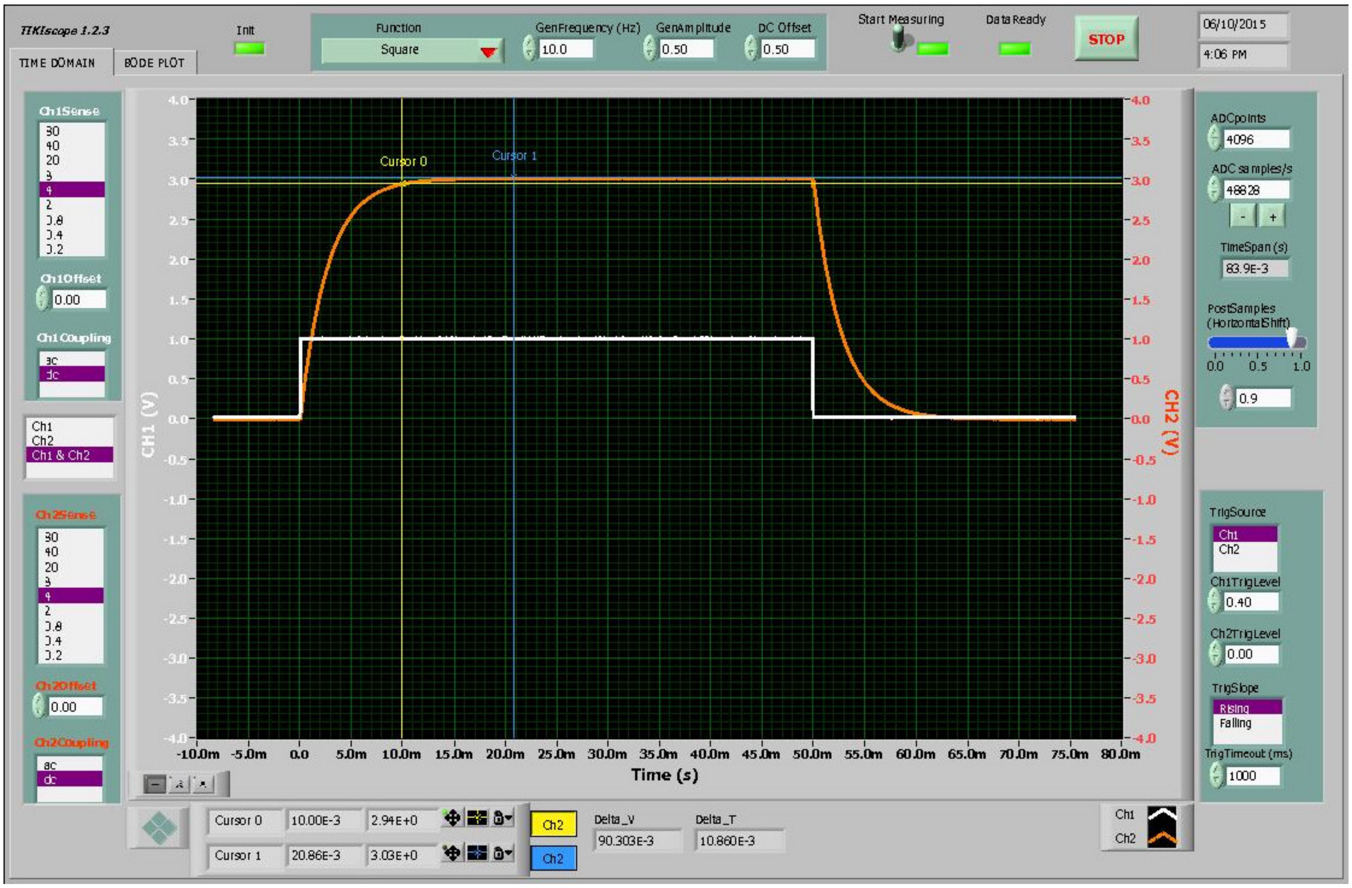

Figure 4: Settling time for open-loop configuration

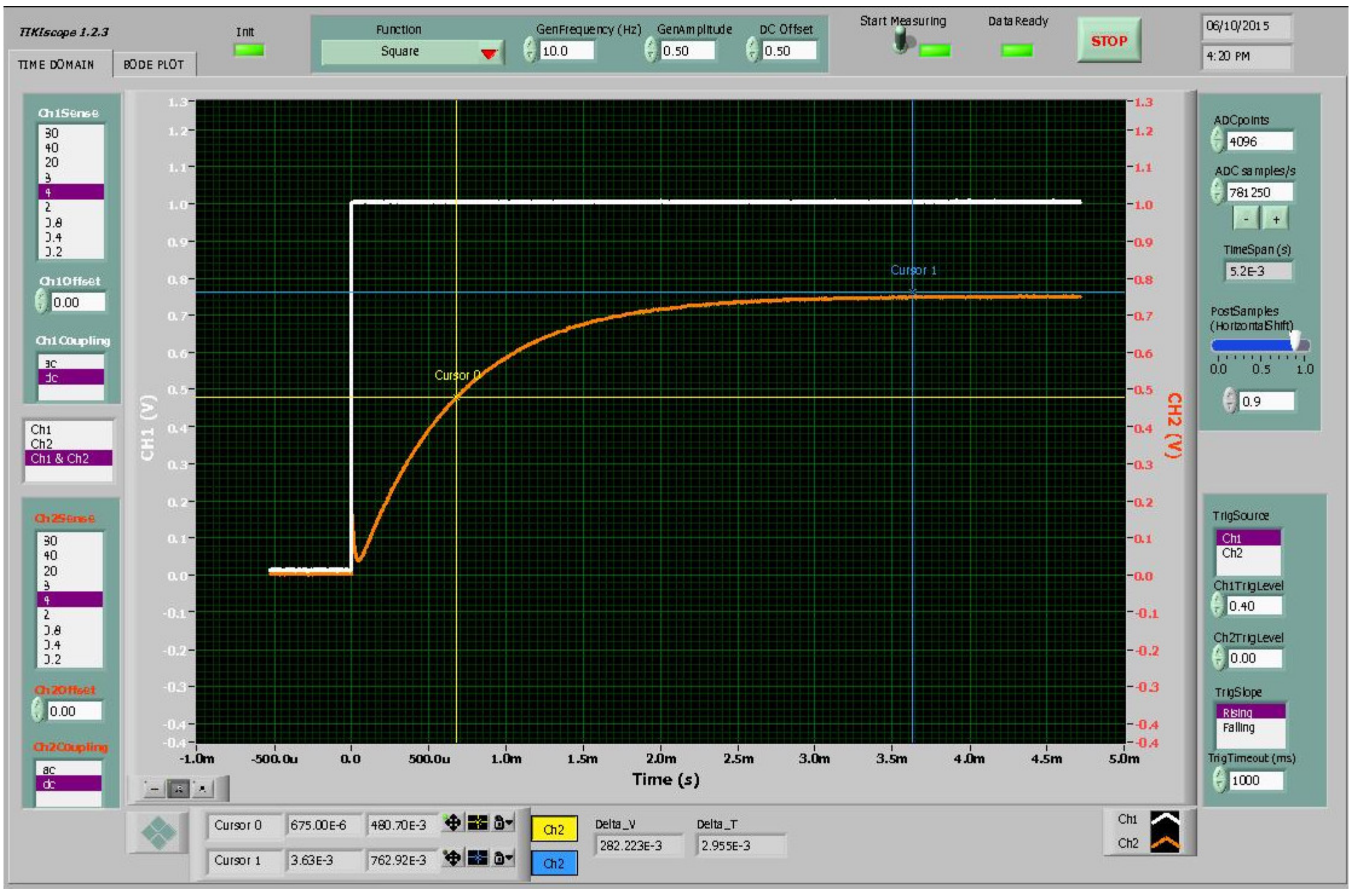

Figure 5: Time constant for closed-loop configuration

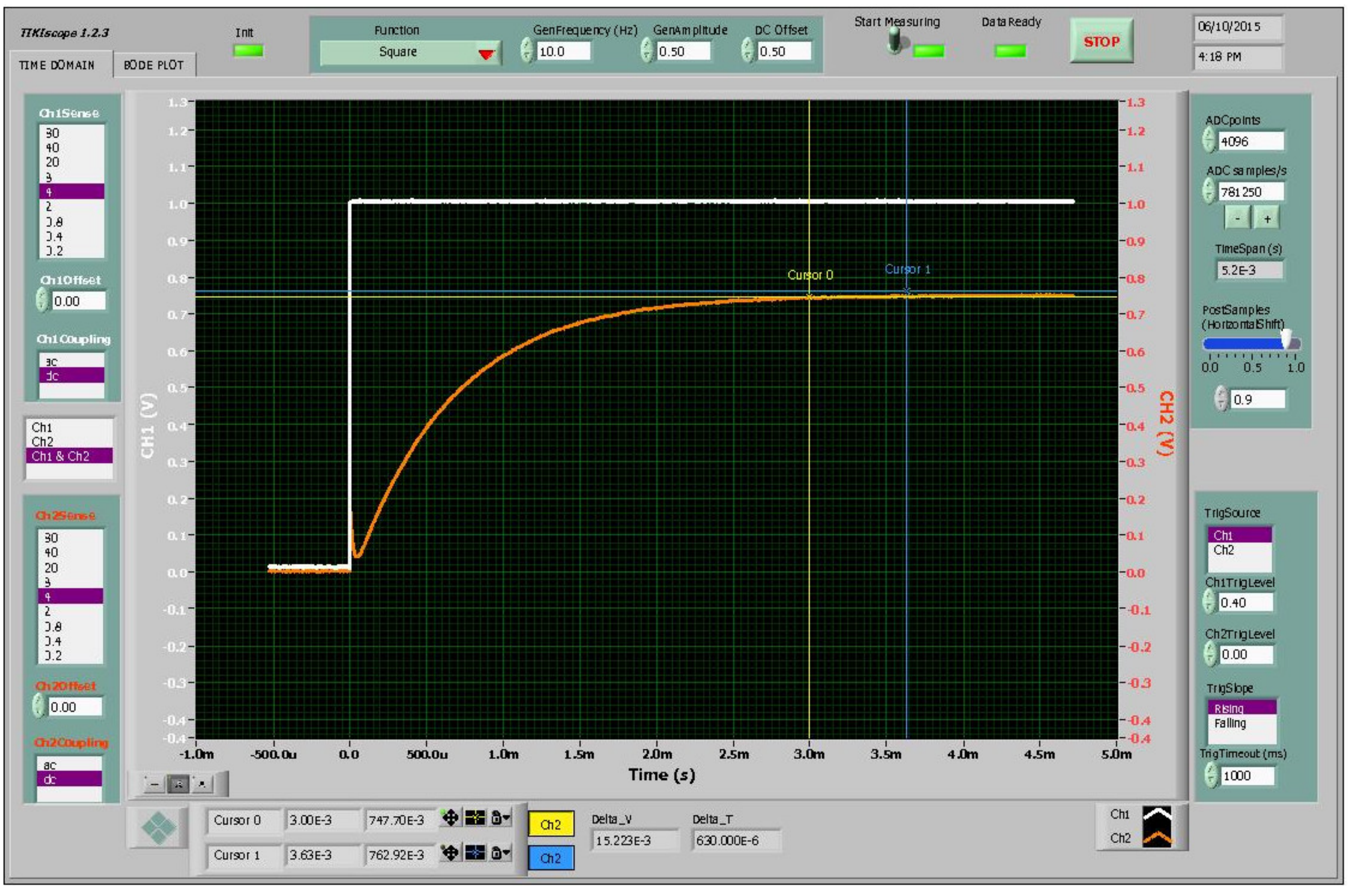

Figure 6: Settling time for closed-loop configuration

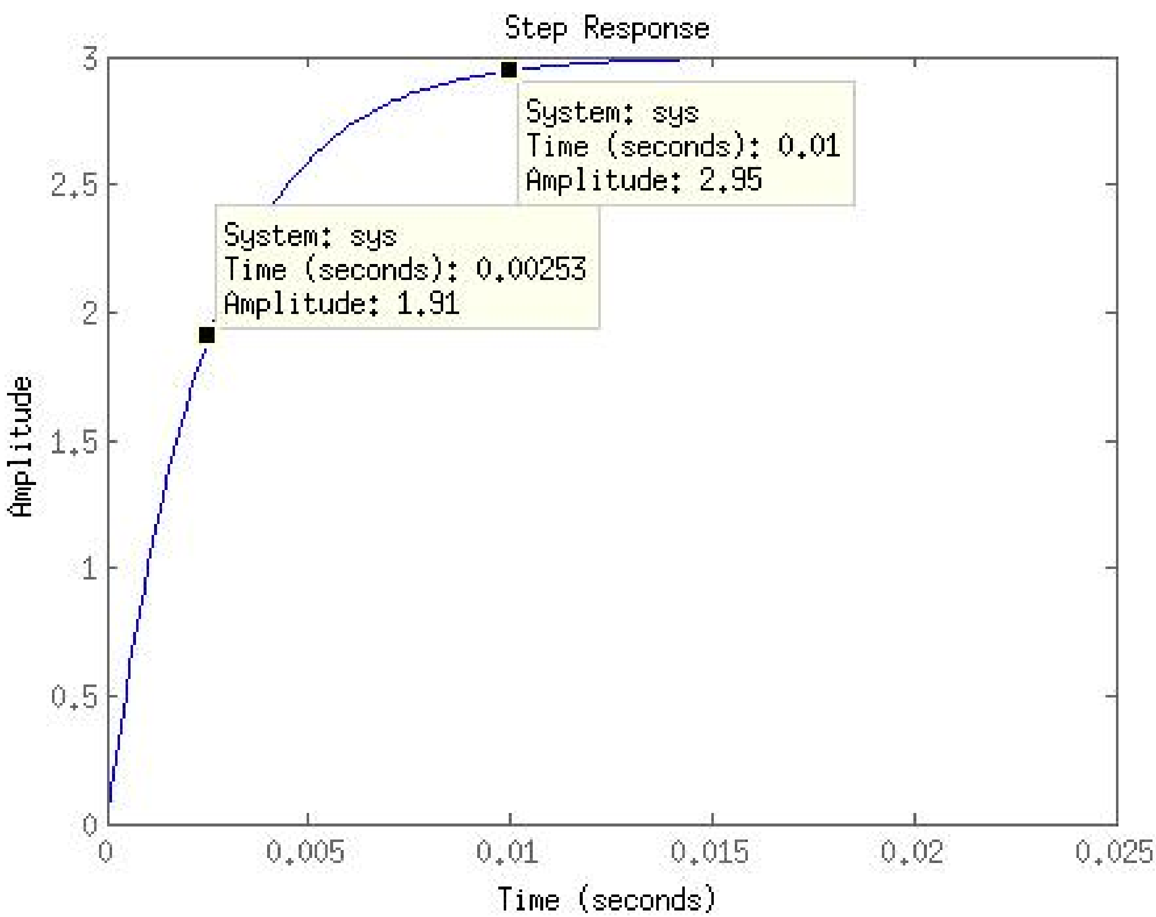

Figure 7: Matlab Open-loop configuration

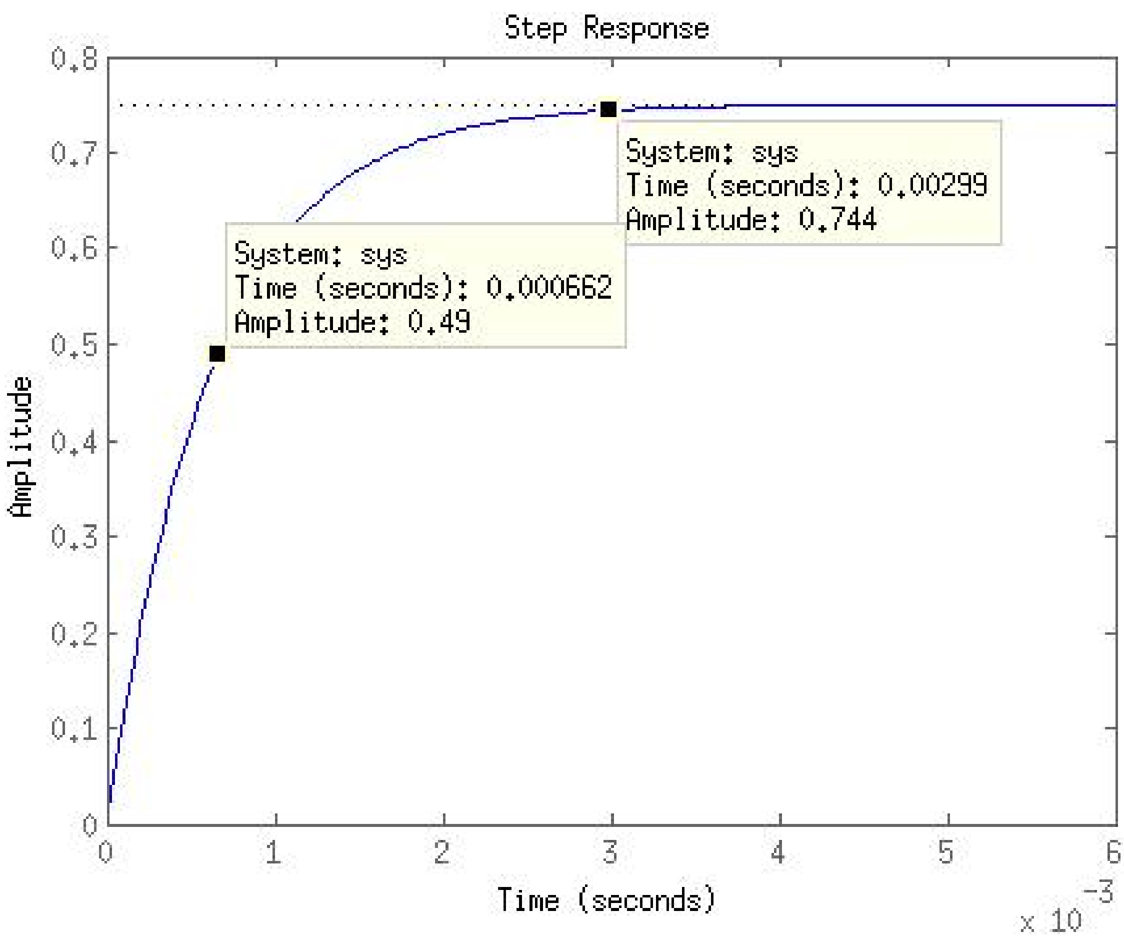

Figure 8: Matlab Closed-loop configuration