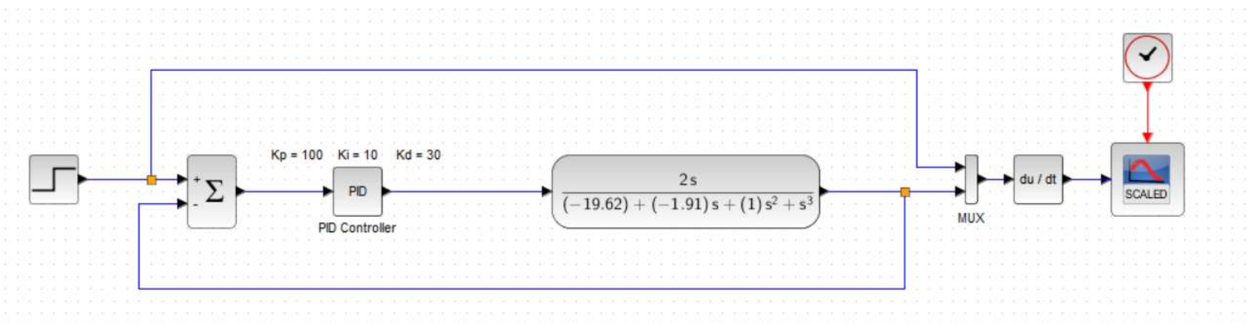
Day 8 – Implement the PID Controller

Xcos Block Diagram:

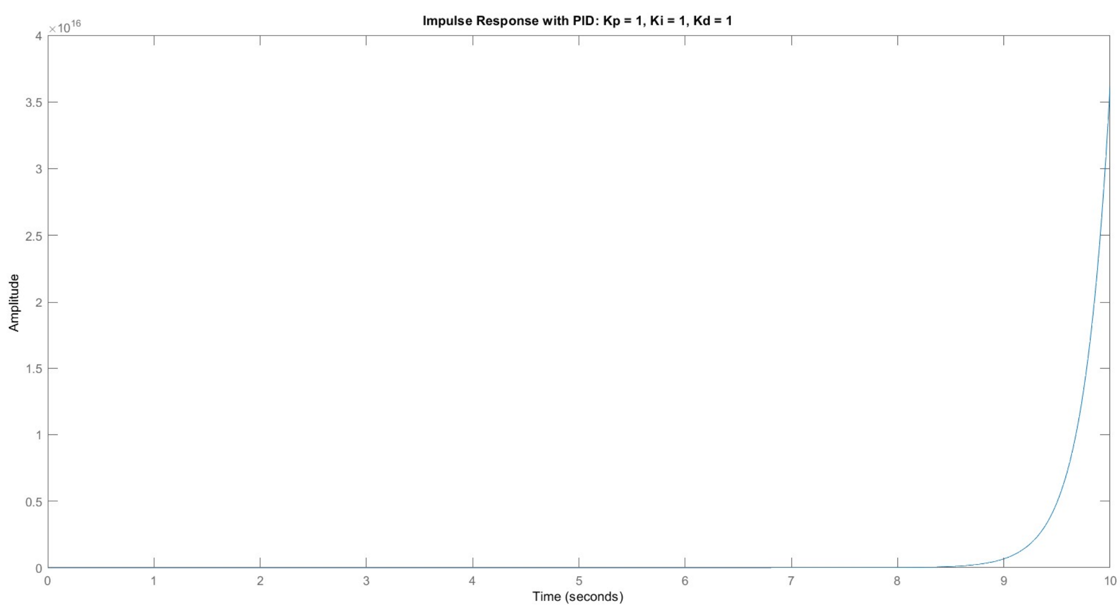


Combination of K_p, K_d, K_i:

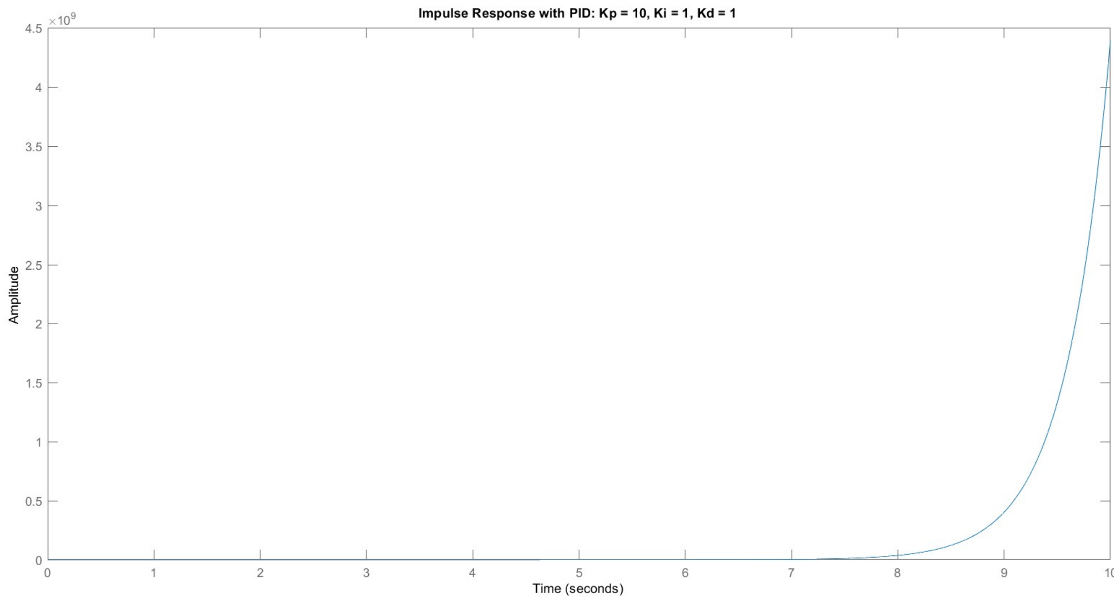
Cases	K_p	Ki	K_d
Case 1	1	1	1
Case 2	10	1	1
Case 3	100	1	1
Case 4	100	10	1
Case 5	100	1	10
Case 6	100	10	30

The impulse response for the above cases:

<u>Case 1:</u>

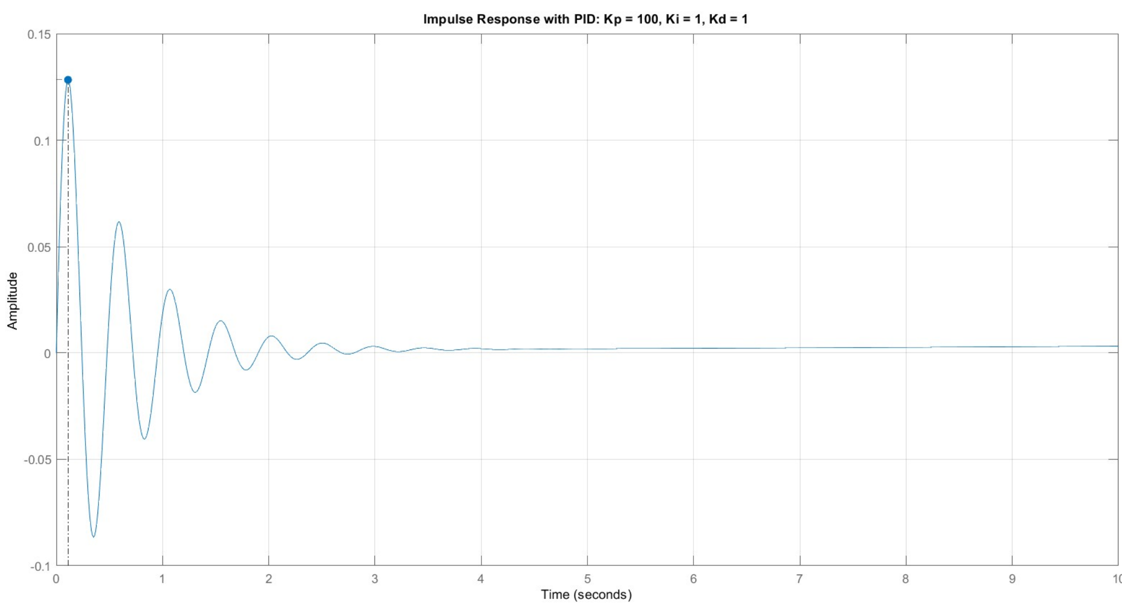


Case 2:



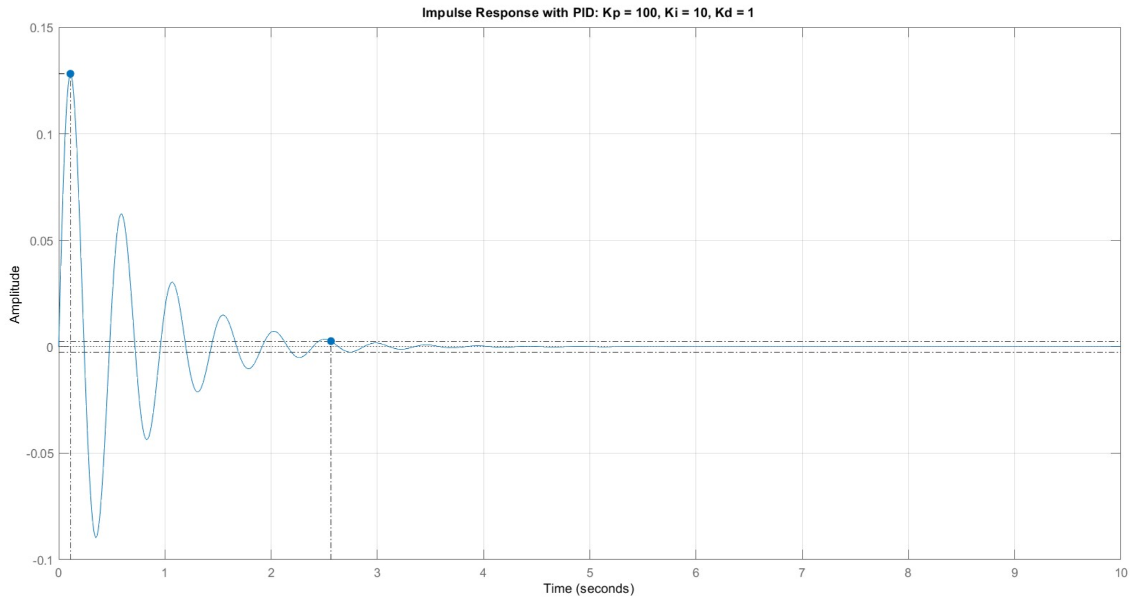
Impulse Response with PID: Kp = 10, Ki = 1, Kd = 1
×10^9
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Amplitude
0
1
2
3
4
5
6
7
8
9
10
Time (seconds)

Case 3:



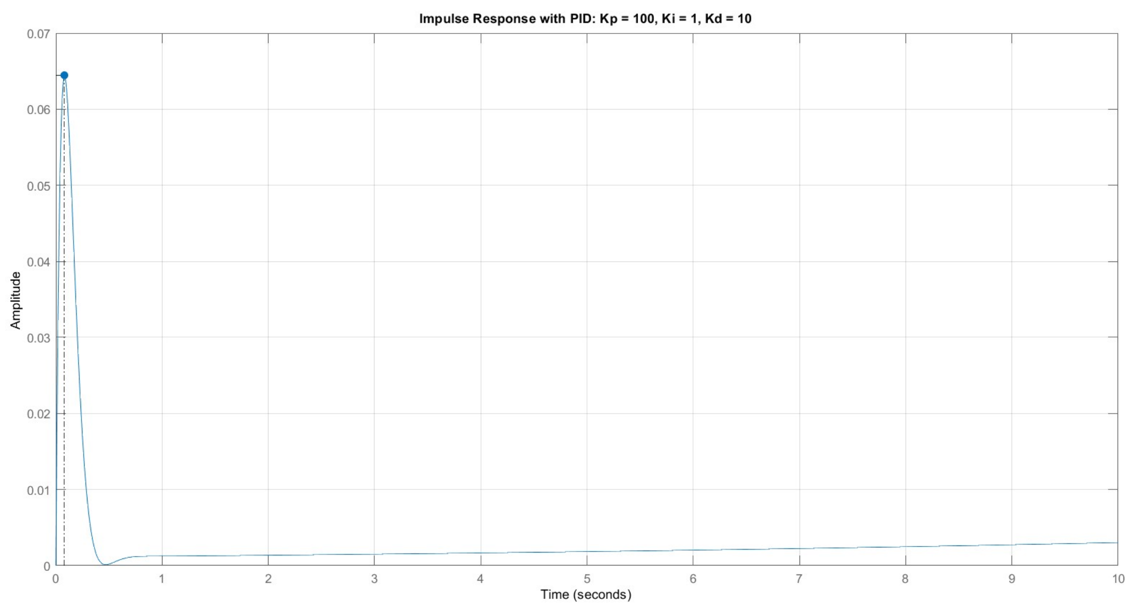
Impulse Response with PID: Kp = 100, Ki = 1, Kd = 1
0.15
0.1
0.05
0
-0.05
-0.1
Amplitude
0
1
2
3
4
5
6
7
8
9
10
Time (seconds)

Case 4:



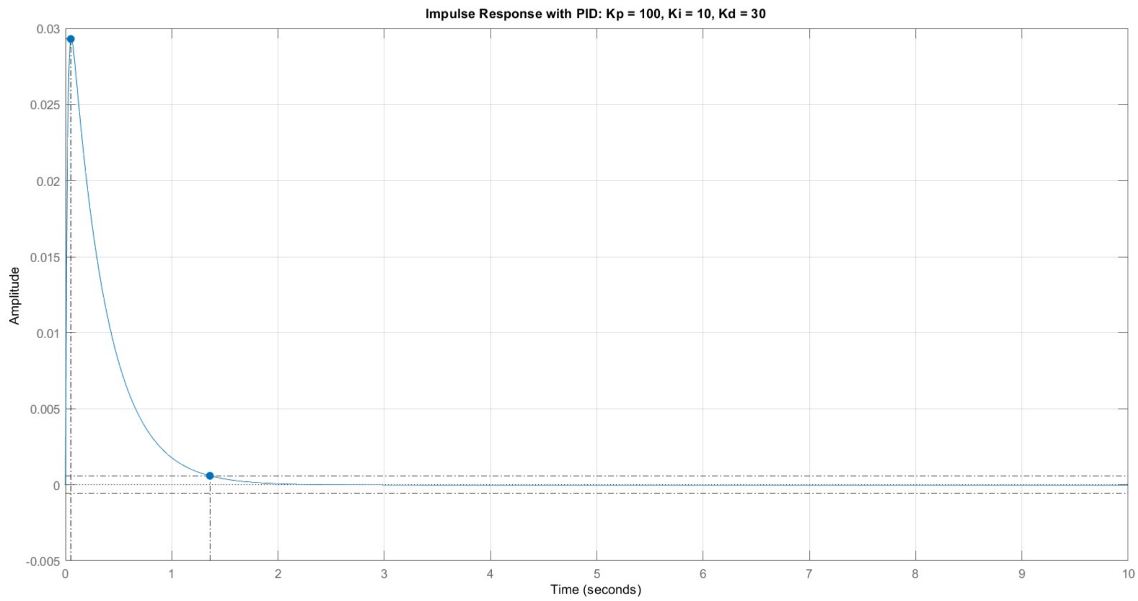
Impulse Response with PID: Kp = 100, Ki = 10, Kd = 1
Amplitude
Time (seconds)
0.15
0.1
0.05
0
-0.05
-0.1
0
1
2
3
4
5
6
7
8
9
10

Case 5:



Impulse Response with PID: Kp = 100, Ki = 1, Kd = 10
Amplitude
Time (seconds)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
1
2
3
4
5
6
7
8
9
10

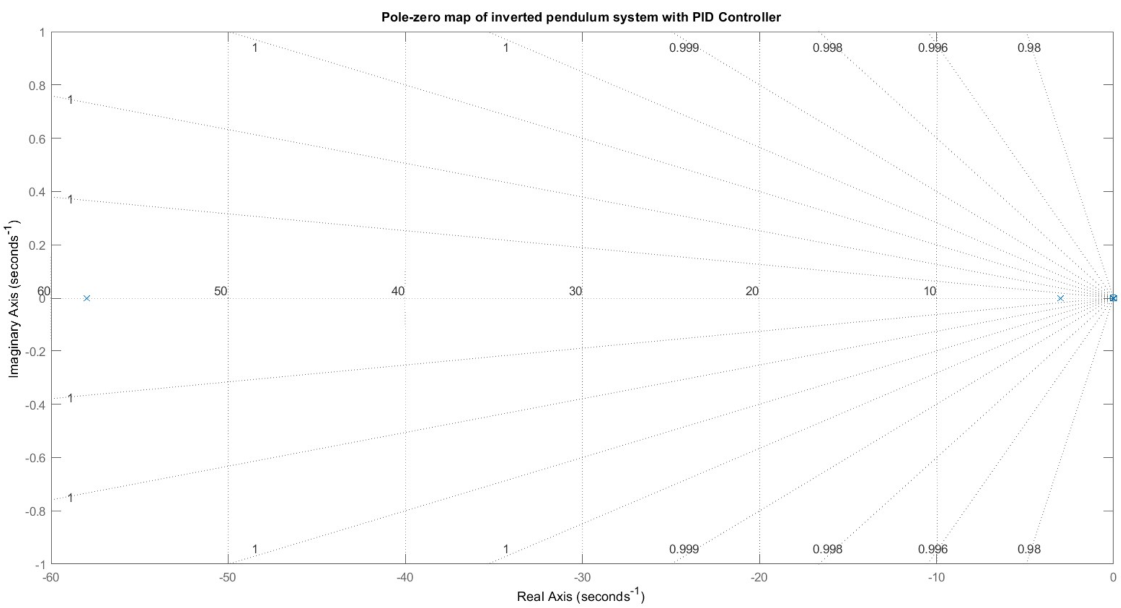
Case 6:

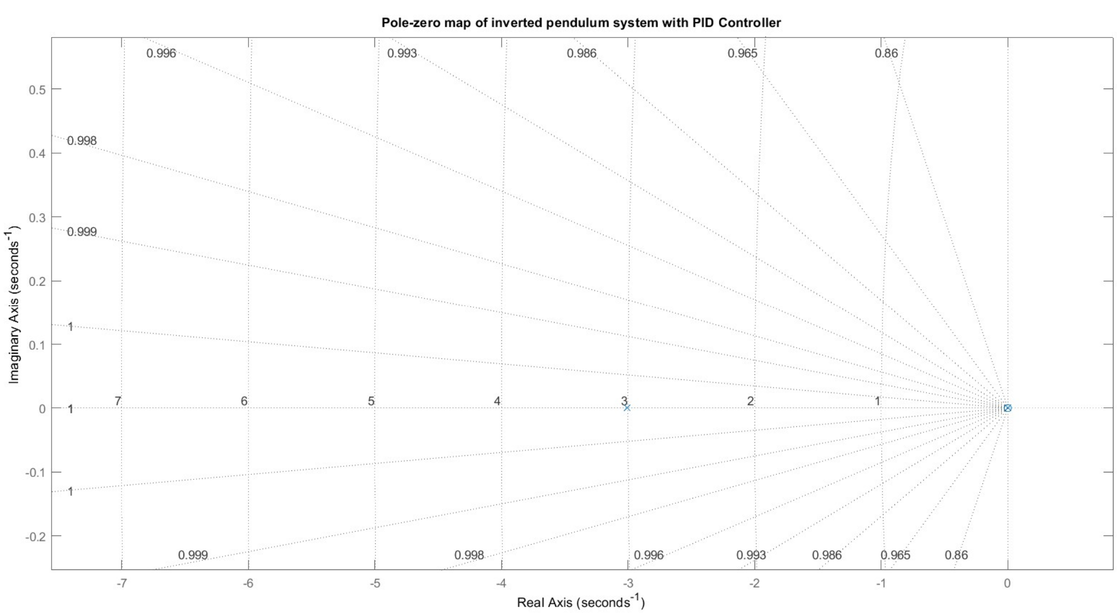


Comments:

Cases	Comments/Remarks
Case 1: $K_p = 1$, $K_i = 1$, $K_d = 1$	Unbounded output → unstable response
Case 2: $K_p = 10$, $K_i = 1$, $K_d = 1$	Unbounded output → unstable response
Case 3: $K_p = 100$, $K_i = 1$, $K_d = 1$	Oscillatory response for some time, then gets stable but does not stabilizes at 0
Case 4: $K_p = 100$, $K_i = 10$, $K_d = 1$	Oscillatory response for some time, then gets stabilize at 0, high settling time
Case 5: $K_p = 100$, $K_i = 1$, $K_d = 10$	No oscillations, settles at a constant quantity but not at 0
Case 6: $K_p = 100$, $K_i = 10$, $K_d = 30$	Optimum response, gets stable at 0 with min overshoot and rise time, settling time.

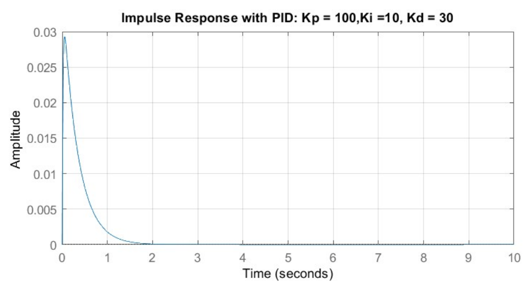
Pole – Zero Plot for best K_p and K_d (*Case 6*):

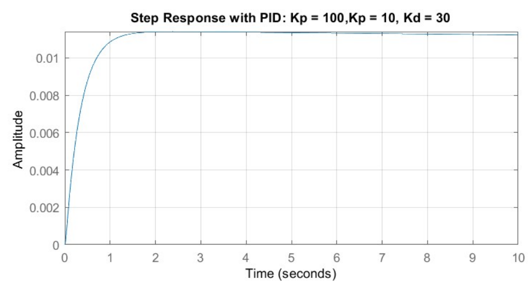


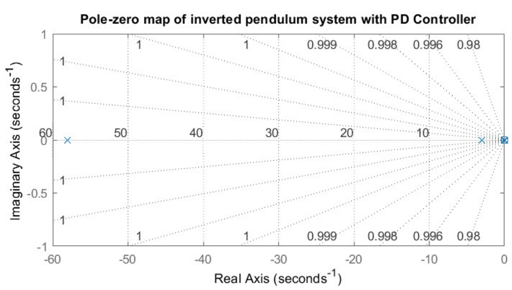


On observing the pole and zero plot, the pole on RHP in PD controller plot is now not on the RHP, lies on the imaginary axis. The problem of the instability of the system with PD controller is resolved by PID, this is due to the K_i. As to have a best stable system the poles should be far from the imaginary axis, and to move the pole on the imaginary axis far away, there is need of increasing K_i which on increasing beyond a threshold value (here beyond 10) will make the system less stable, by giving the response below 0.

Impulse, Step response and pole-zero plot:







Conclusion/Outcomes:

- By using the PID Controller, trying to stabilize the inverted pendulum system and overcome the problem of a pole on RHP in case of using a PD controller.
- **K_p:** On increasing the proportional gain K_p, the unbounded output gets bounded at a certain value of K_p, this parameter increases the peak overshot M_p.
- **K_i:** On increasing the integral gain K_i, the steady state response gets improves and we get a stable output. This parameter brought the pole from RHP to LHP in s-plane and made the system stable. On further increasing K_i (>10 in our case), the response shifts below 0 and it makes the system less stable, hence proper tuning is must.
- **K_d:** On increasing the derivative gain K_d, the transient response gets improves and the oscillations are overcome which were caused due the K_p gain. This brings the response near to 0 and stabilizes it.
- Hence, by using PID controller, the inverted pendulum system is stabilized and he PD controller problem is overcome, by observing the impulse response of the system.