Questions : What is the bandwidth of the bike ? How does the bandwidth of the balancing control loop impact the response of the bike to disturbances ? How does including the inertia of the front wheel in the bike model influence the bandwidth of the balancing control loop ?

Plan :

* Write equations for the balancing control loop in steady-state. Compute the gains from disturbances to true steering angle. Is a D or I term needed/should be avoided ?
* Confirm in simulation.

Conclusion : The equation giving the true steering angle as a function of reference roll, reference steering angle and steering angle disturbance does not contain the PID transfer function, therefore the choice of PID gains has no impact during steady-state.

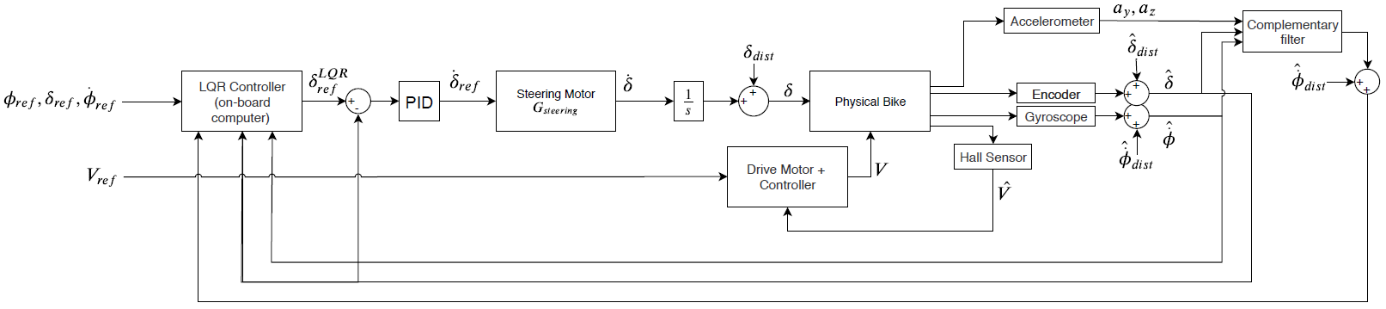


Figure - Block diagram of the balancing control loop

The bandwidth of the bike (from true steering angle to true roll ) is 0.5Hz.

The three reference inputs to the system (roll reference , roll rate reference , steering angle reference ) have similar effect on the system down to a gain as the LQR controller operates a linear combination of these signals. The measured roll perturbation acts in the same way to a change in references. Therefore, the bandwidth of the system will be presented only for as it will have the same value for the three references.

Even though bandwidths are identical, Bode plots from perturbations on roll/roll rate/steering angle to true roll/roll rate/steering angle are not identical to Bode plots from reference roll/roll rate/steering angle to true roll/roll rate/steering angle.

We compare the bandwidth of the system for 3 different LQR controller :

* ‘slow’ LQR :
* ‘medium LQR :
* ‘fast’ LQR :

Figure 2 shows the bandwidth of the system for various input-output combinations. In this table, bandwidth related to the ‘slow’ LQR will be written in blue color, yellow color for the ‘medium’ LQR and red for the ‘fast’ LQR.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| From  To | Measured Roll Perturbation | | Measured Roll Rate Perturbation | | Measured Steering Angle Perturbation | |
| True Roll | 0.155  0.515  2.845 |  | 0.130  0.217  0.238 |  | 0.118  0.195  0.226 |  |
| True Roll Rate | Inf  Inf  Inf |  | Inf  Inf  Inf |  | 25.754  26.698  34.359 |  |
| True Steering Angle | 0.173  10.684  23.853 |  | 0.138  0.271  0.327 |  | 0.124  0.227  0.288 |  |

Figure - Bandwidth of the balancing control loop for various input-output combinations.