



作业一：内模控制器的设计：

使用 Simulink 对内模控制器进行设计与仿真：

对纯滞后阶段做一阶 Pade 近似，并：

$$e^{-\theta} \approx \frac{-0.5\theta s + 1}{0.5\theta s + 1}$$

设计理想控制器如下：

$$\hat{G}_{\text{IMC}}(s) = \frac{(\tau_p s + 1)(0.5\theta s + 1)}{K}$$

考虑加入滤波器，其中滤波器参数 α 取 2.3

$$\begin{aligned} G_{\text{IMC}}(s) &= \hat{G}_{\text{IMC}}(s)G_f(s) = \hat{G}_p^{-1}(s)G_f(s) \\ &= \frac{(\tau_p s + 1)(0.5\theta s + 1)}{K} \cdot \frac{1}{\alpha s + 1} \end{aligned}$$

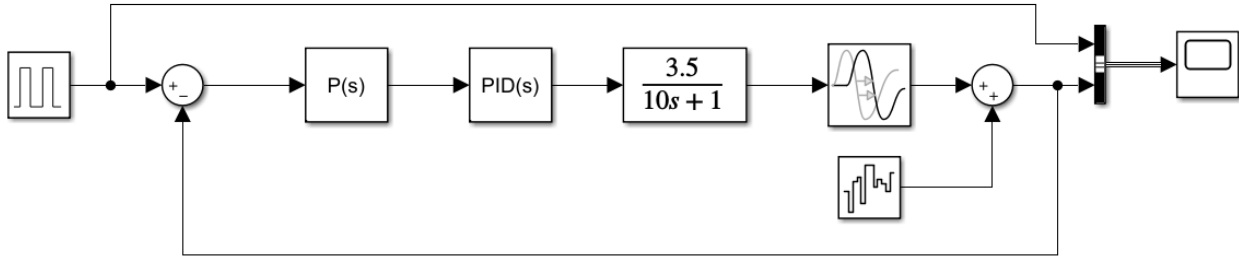
则，对整个控制器进行化简为一个 PID 控制器如下：

$$\begin{aligned} G_c(s) &= \frac{G_{\text{IMC}}(s)}{1 - \hat{G}_p(s)G_{\text{IMC}}(s)} = \frac{\hat{G}_{\text{IMC}}(s)G_f(s)}{1 - \hat{G}_p(s)\hat{G}_{\text{IMC}}(s)G_f(s)} \\ &= \frac{\hat{G}_{\text{IMC}}(s)G_f(s)}{1 - \hat{G}_p(s)\hat{G}_p(s)\hat{G}_{\text{IMC}}^{-1}(s)G_f(s)} \\ &= \left[\frac{1}{K} \right] \frac{(\tau_p s + 1)(0.5\theta s + 1)}{(\alpha + 0.5\theta)s} \end{aligned}$$

最终设计得到的 PID 控制器具体参数为：

$$G_c(s) = \left[\frac{1}{3.5} \right] \frac{(10s + 1)(1.5s + 1)}{3.8s}$$

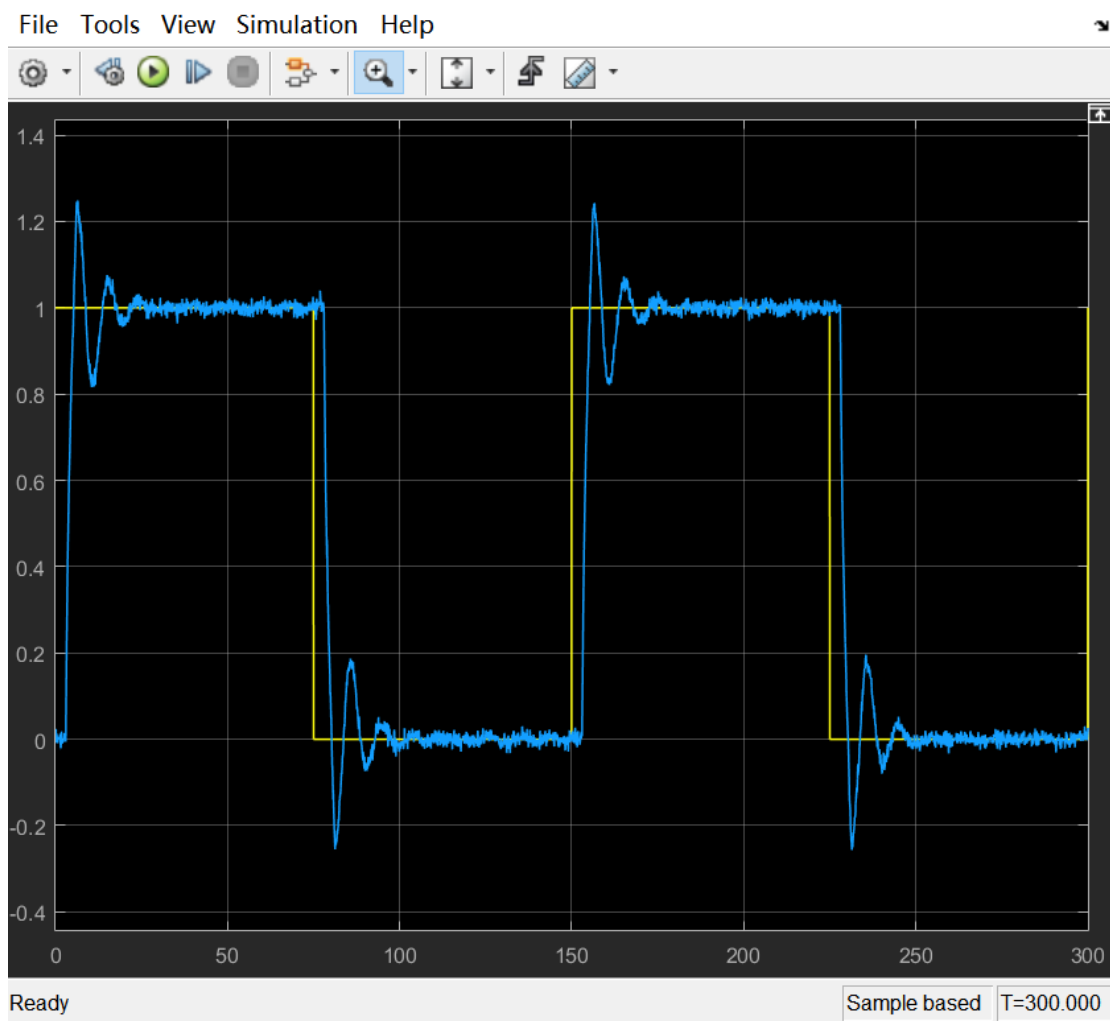
在 Simulink 中仿真框图如下：



其中具体参数如下:

$$Kp_1 = \frac{1}{3.5} \quad Kp_2 = \frac{11.5}{3.8} \quad Ki_2 = \frac{1}{3.8} \quad Kd_2 = \frac{15}{3.8}$$

设计最终效果图 (加入白噪声) 如下所示:





作业二：Smith 控制系统的设计：

The diagram illustrates a closed-loop control system. The reference input is a square wave, which enters a summing junction (+). The feedback signal is subtracted at this junction (-). The output of the first summing junction goes through another summing junction (+) before entering the PID controller block. The output of the PID controller passes through a transfer function block $\frac{-10.9}{21s + 1}$. This output is then compared with the reference input at a third summing junction (+). The resulting error signal is fed back through a transfer function block $\frac{-10.9}{21s + 1}$ and a scope (oscilloscope icon) before being subtracted from the reference input at the first summing junction (-). The final output of the system is shown as a smooth curve on a scope.

$$Kp = -1.2 \quad Ki = -0.6 \quad Kd = -2$$