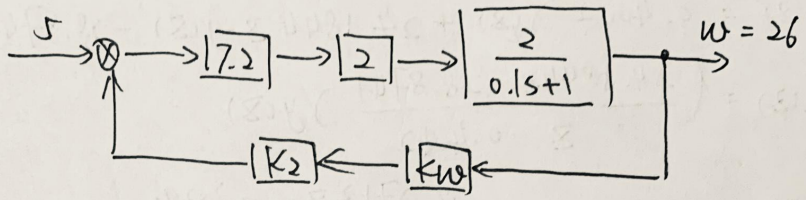
(1). D/A = 120mV 时电机启动, $u=(D/A)_0 \cdot k_1 \cdot k_3 = 0.24k_1$.

$u > u_A = 1.7V \Rightarrow 0.24k_1 > 1.7$

$\therefore k_1 > 7.083$, 取 $k_1 = 7.2$.

(2). D/A = 5V 时, $w = 26 rad/s$, 此时闭环回路为:



$\therefore$ 稳态时, $(5 - 26 \times k_2 k_w) \times 7.2 \times 2 \times 2 = 26$

$\therefore k_2 k_w = 0.1576$.

$\therefore$ 模拟部分传递函数为: $G(s) = \dfrac{\frac{7.2\times4}{0.1s+1}\cdot\frac{1}{s}}{1+0.1576\times\frac{7.2\times4}{0.1s+1}} = \dfrac{288}{(s+43.389)s}$.

取状态参数 $x = \begin{bmatrix}\theta\\ w\end{bmatrix}$, $\begin{bmatrix}\dot{x}_1(t)\\ \dot{x}_2(t)\end{bmatrix} = \begin{bmatrix}0 & 1\\ 0 & -43.389\end{bmatrix}\begin{bmatrix}x_1(t)\\ x_2(t)\end{bmatrix} + \begin{bmatrix}0\\ 288\end{bmatrix}u(t)$.

$y(t) = \begin{bmatrix}1 & 0\end{bmatrix}\begin{bmatrix}x_1(t)\\ x_2(t)\end{bmatrix}$, $T = 0.01s$.

$\therefore$ 离散状态方程为:

$$\begin{bmatrix}x_1(k+1)\\ x_2(k+1)\end{bmatrix} = \begin{bmatrix}1 & 0.0077\\ 0 & 0.5747\end{bmatrix}\begin{bmatrix}x_1(k)\\ x_2(k)\end{bmatrix} + \begin{bmatrix}0.0121\\ 2.2113\end{bmatrix}u(k)$$

(3). $\zeta > 0.9$, 取 $\zeta = 0.95$. $\omega_n > 20$, 取 $\omega_n = 25 rad/s$. $T = 0.01s$.

$s_{1,2} = -\zeta\omega_n \pm j\omega_n\sqrt{1-\zeta^2} = -23.75 \pm 7.8062j$

$z_{1,2} = e^{-s_{1,2}T} = 0.7862 \pm 0.0615j$

$\therefore K = [2.2382, -0.0112]$

(4). 闭环极点为 $\sigma = \omega_n\zeta = 23.75$. 取观测器极点为 $e^{-23.75\times4\times0.01} = 0.3867$.

$\therefore$ 令 $\det[zI - F_{22} + LF_{12}] = 0$

$L = 24.4104$

(5). $G_{12} - \angle G_1 = 1.9166$.

$$\begin{cases} \tilde{x}_2(k+1) = 0.3874\,\tilde{x}_2(k) + 24.5844[y(k+1)-y(k)] + 1.9166\,u(k). \\ u(k) = -2.2382\,y(k) + 0.0112\,\tilde{x}_2(k) \end{cases}$$

$$\therefore \tilde{x}_2(k+1) = 0.4082\,\tilde{x}_2(k) + 24.5844y(k+1) - 28.8741\,y(k)$$

$$z\cdot\tilde{x}_2(z) = 0.4082\,\tilde{x}_2(z) + 24.5844\,z\,y(z) - 28.8741\,y(z)$$

$$\tilde{x}_2(z) = \left(\frac{24.5844z - 28.8741}{z - 0.4082}\right) y(z)$$

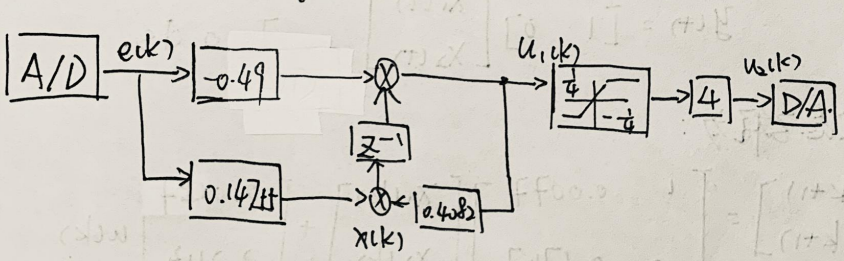
$$\therefore u(z) = -2.2382\,y(z) + \frac{0.2743z - 0.3234}{z - 0.4082}\,y(z)$$

$$D(z) = \frac{u(z)}{y(z)} = -2.2382 + \frac{0.2743z - 0.3234}{z - 0.4082} = \frac{-1.9629z + 0.5902}{z - 0.4082}.$$

(6). 使闭零极型, $D(z) = \dfrac{-1.9629 + 0.5902z^{-1}}{1 - 0.4082z^{-1}}$.

$$D(z)\Big|_{\substack{z\to 1\\ t\to\infty}} = \frac{-1.9629 + 0.5902}{1 - 0.4082} = -2.3194.$$

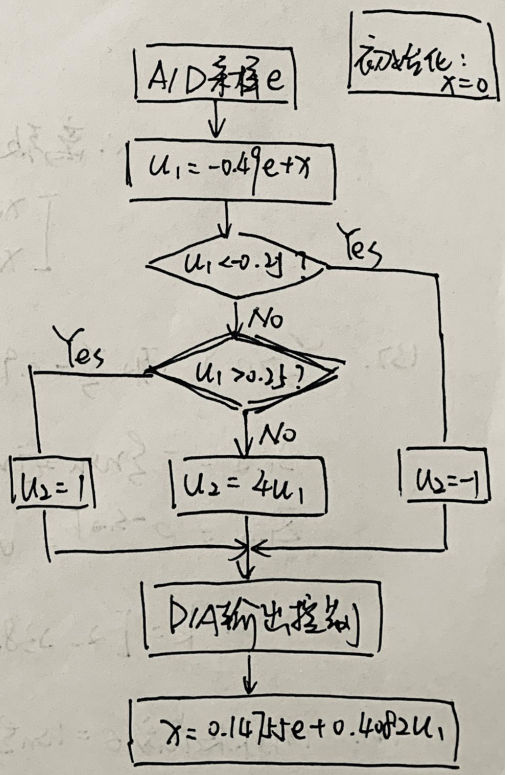
$$D(z)\Big|_{\substack{z\to -1\\ t\to\infty}} = -1.813$$ 选择比例因子为 $2^2 = 4$.



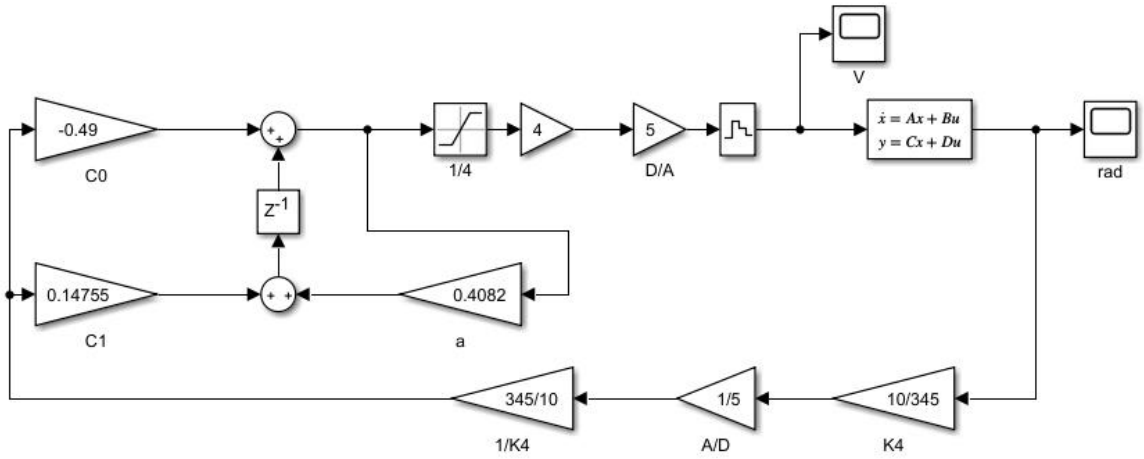
算法Ⅰ: $u_1(k) = -0.49e(k) + x(k-1)$.

$$u_2(k) = \begin{cases} -1, & u_1(k) < -0.25 \\ 4u_1(k), & |u_1(k)| \le 0.25 \\ 1, & u_1(k) > 0.25 \end{cases}$$

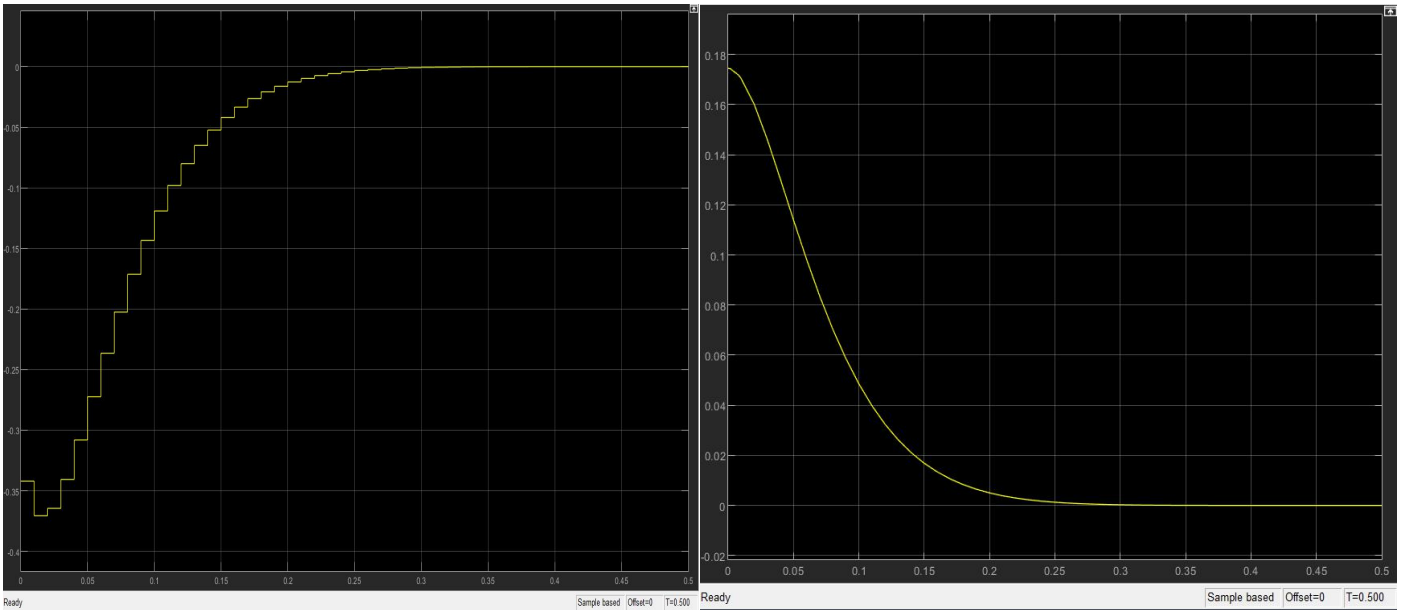
算法Ⅱ: $x(k) = 0.1474e(k) + 0.4082\,u_1(k)$.



(7) 扰动仿真结果：

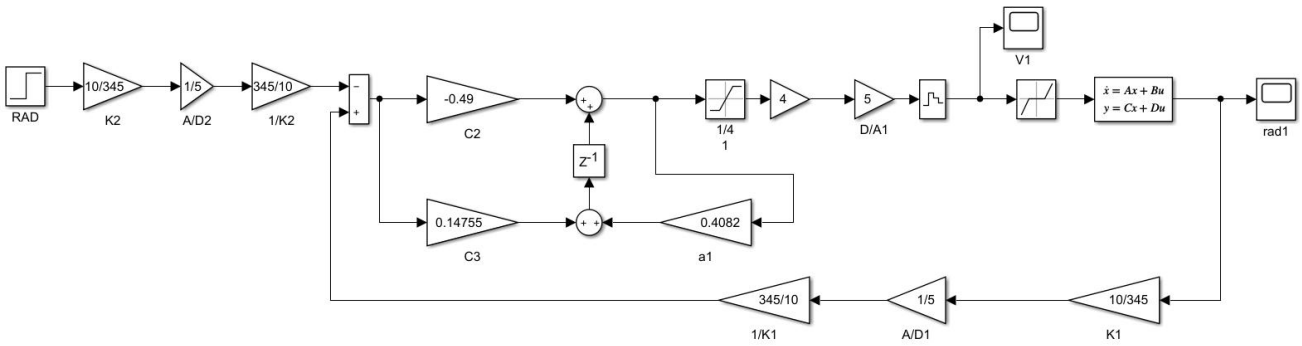


搭建如上模型，对于初始状态[0.1745 0]，进行扰动仿真，得到如下结果：

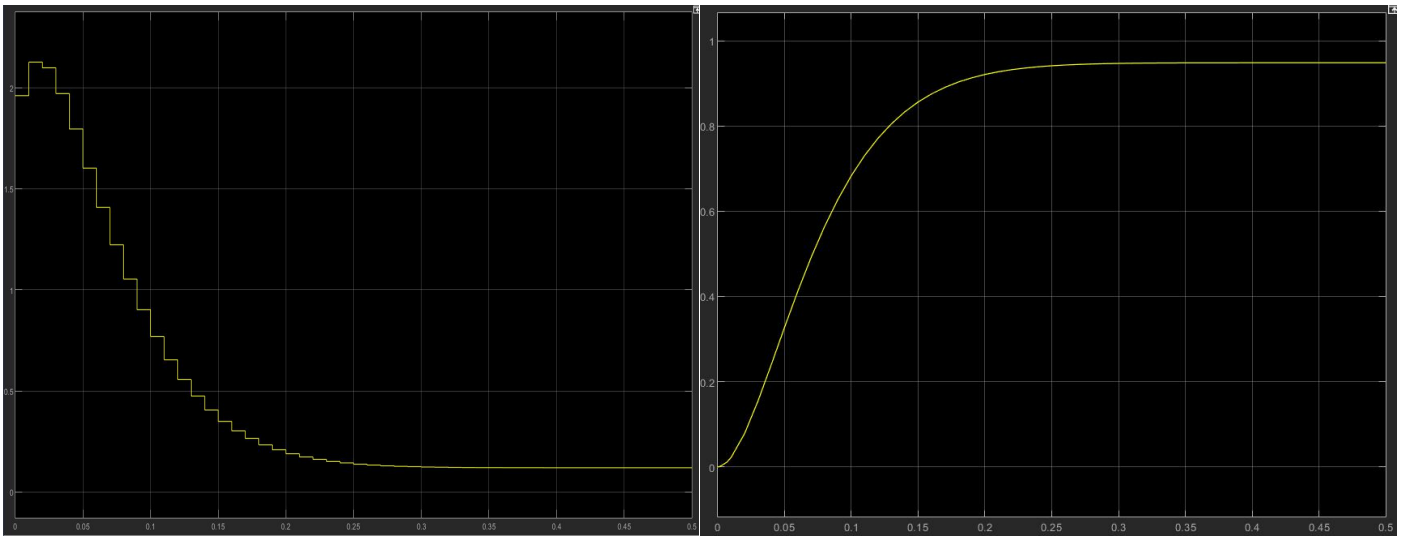


上图中左图为 V，右图为 rad；可以看出，在很短时间内(0.25s)，系统回到初始平衡零点。说明系统设计成功。

(8) 引进指令信号，搭建如下模型：



初始状态为[0 0]，输入信号为阶跃信号，幅值为 1，进行仿真，得到如下结果：



上图中左图为 V，右图为 rad；可以看出，系统可以做到跟随，说明设计成功。由于 120mV 死区的存在，输出无法达到 1。

B7-19. $D(z)=\dfrac{0.5z-0.42}{z^2-1.1z+0.3}=\dfrac{0.5z^{-1}-0.42z^{-2}}{1-1.1z^{-1}+0.3z^{-2}}$

直接法：$D(z)=(0.5z^{-1}-0.42z^{-2})\cdot\dfrac{1}{1-1.1z^{-1}+0.3z^{-2}}$

串联法：$D(z)=\frac{1}{5}\cdot(25z-21)\cdot\dfrac{1}{z\cdot2-1}\cdot\dfrac{1}{5z-3}=2.5\cdot\dfrac{1-0.84z^{-1}}{1-0.5z^{-1}}\cdot\dfrac{0.2z^{-1}}{1-0.6z^{-1}}$

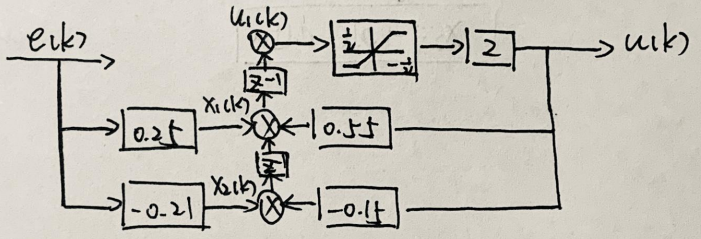
并联法：由上式，可得 $D(z)=\dfrac{1.7z^{-1}}{1-0.5z^{-1}}-\dfrac{1.2z^{-1}}{1-0.6z^{-1}}$

$$D(z)\Big|_{\substack{z\to1\\t\to\infty}}=\frac{0.5-0.42}{1-1.1+0.3}=\frac{0.08}{0.2}=0.4$$

$$D(z)\Big|_{\substack{z\to-1\\t\to\infty}}=\frac{-0.5-0.42}{1+1.1+0.3}=\frac{-0.92}{2.4}=-0.383$$

$|D(1)|<1$，$|D(-1)|<1$，选择比例因子 $2^1=2>1$.

结构编排图：



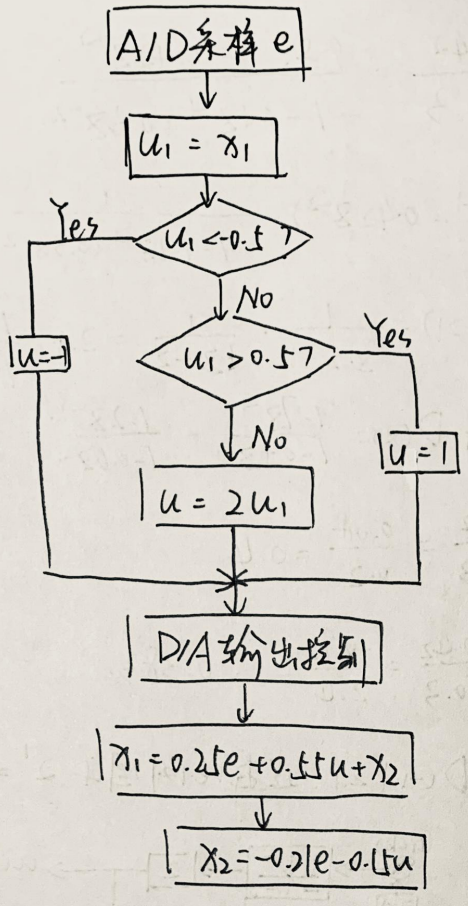
算法Ⅰ：$u_1(k)=x_1(k-1)$.

$$u(k)=\begin{cases}-1, & u_1(k)<-0.5\\ 2u_1(k), & |u_1(k)|\le0.5\\ 1, & u_1(k)>0.5\end{cases}$$

算法Ⅱ：$x_1(k)=0.25e(k)+0.55u_1(k)+x_2(k-1)$

$x_2(k)=-0.21e(k)-0.15u(k)$.

流程图：



初始化：$x_1 = 0$
$x_2 = 0$