1 Param

$$\mathbf{H}(z^{-1}) = z^{-1}\frac{k_o(1+bz^{-1})}{(1-p_1z^{-1})(1-p_2z^{-1})}\mathbf{B} = z^{-1}\frac{k_o(1+bz^{-1})}{1-a_1z^{-1}-a_2z^{-2}}\mathbf{B} = H(z^{-1})\mathbf{B}$$

$$k_o = 5.6695\times 10^{-4},\quad b = 0.9782,\quad a_1 = 1.934848,\quad a_2 = -0.935970,\quad T = 10^{-5}\text{ s}$$

$$k_c = \frac{1-\lambda_c}{1+b},\quad b_c = bk_c = \frac{1-\lambda_c}{1+1/b},\quad k_u = \frac{k_c}{k_o}$$

$$\lambda_c = e^{-f_{B_c}\cdot 2\pi T},\quad \lambda_e = e^{-f_{B_e}\cdot 2\pi T},\quad \beta = \sqrt{\lambda_e\lambda_c}$$

Estimator gains:

$$\begin{cases} \ell_1 = \lambda_c + (1+\beta) - 3\lambda_e \\ \ell_2 = \dfrac{b(\lambda_e-1)^3 - \beta(b+1)(\beta^2-3\beta\lambda_e+\beta+3\lambda_e^2-3\lambda_e+1)}{k_c(b+1)(b+\beta)} \\ \ell_3 = -\dfrac{\beta+b+\beta b-3\beta\lambda_e-3b\lambda_e+b\beta^2+3b\lambda_e^2+\beta^2+\lambda_e^3-3\beta b\lambda_e}{k_c(b+1)(b+\beta)} \end{cases}$$

2 Estimator

Initialization:

$$\mathbf{v}_f[k] = \frac{1}{(1-\lambda_c)(1+b)}\left\{b\mathbf{v}_d[k+d] + (1-b\lambda_c)\mathbf{v}_d[k+d-1] - \lambda_c\mathbf{v}_d[k+d-2]\right\}\quad (d=2)$$

$$\delta\mathbf{v}_f[k-1] = \mathbf{v}_f[k] - (1-b_c)\mathbf{v}_f[k-1] - b_c\mathbf{v}_f[k-2]$$

$$\delta\mathbf{v}[k] = \mathbf{v}_f[k] - \mathbf{v}_m[k]$$

$$\begin{cases} \delta\hat{\mathbf{v}}[k] = \lambda_c\delta\hat{\mathbf{v}}[k-1] + \delta\mathbf{v}_f[k-1] + \ell_1\{\delta\mathbf{v}[k-1]-\delta\hat{\mathbf{v}}[k-1]\} \\ \hat{\mathbf{w}}_1[k] = (1+\beta)\hat{\mathbf{w}}_1[k-1] - \beta\hat{\mathbf{w}}_2[k-1] + \ell_2\{\delta\mathbf{v}[k-1]-\delta\hat{\mathbf{v}}[k-1]\} \\ \hat{\mathbf{w}}_2[k] = \hat{\mathbf{w}}_1[k-1] + \ell_3\{\delta\mathbf{v}[k-1]-\delta\hat{\mathbf{v}}[k-1]\} \end{cases}$$

Uncoupled error dynamics (estimation):

$$\begin{bmatrix} e_{\delta v}[k+1] \\ e_{w_1}[k+1] \\ e_{w_2}[k+1] \end{bmatrix} = \begin{bmatrix} \lambda_c-\ell_1 & -k_c & -bk_c \\ -\ell_2 & 1+\beta & -\beta \\ -\ell_3 & 1 & 0 \end{bmatrix}\begin{bmatrix} e_{\delta v}[k] \\ e_{w_1}[k] \\ e_{w_2}[k] \end{bmatrix}$$

3 Control Law

$$\delta\mathbf{v}_c[k] = k_u\delta\mathbf{v}[k] - \hat{\mathbf{w}}_1[k]$$

$$\mathbf{u}[k] = (1-b_c)\mathbf{u}[k-1] + b_c\mathbf{u}[k-2] + \mathbf{B}^{-1}\{\delta\mathbf{v}_c[k] - a_1\delta\mathbf{v}_c[k-1] - a_2\delta\mathbf{v}_c[k-2]\}$$