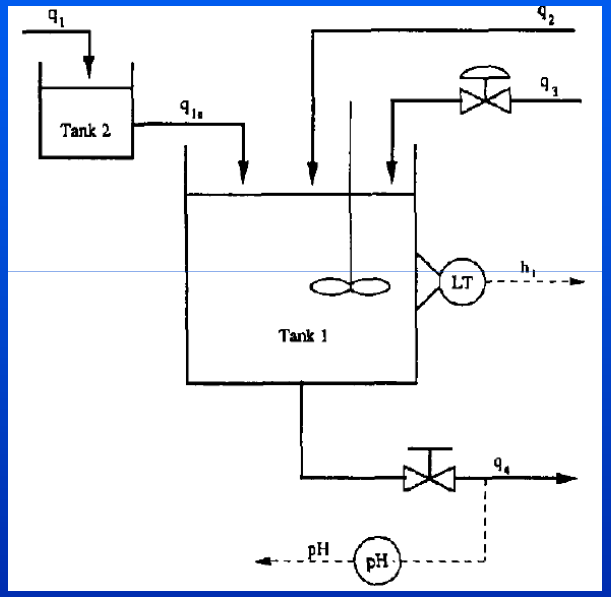
pH process identification

Mathematical model of the process with parameters



$$\dot{x} = f(x) + g(x)u_{a2} + p(x)d$$

$$c(x, y) = 0$$

$$f(x) = \left[\frac{q_1}{A_1 x_3}(W_{a1} - x_1) \;\; \frac{q_1}{A_1 x_3}(W_{b1} - x_2) \;\; \frac{1}{A_1}(q_1 - C_{v4}(h_1 + z)^n) \right]^T$$

$$g(x) = \left[\frac{1}{A_1 x_3}(W_{a3} - x_1) \;\; \frac{1}{A_1 x_3}(W_{b3} - x_2) \;\; \frac{1}{A_1} \right]^T$$

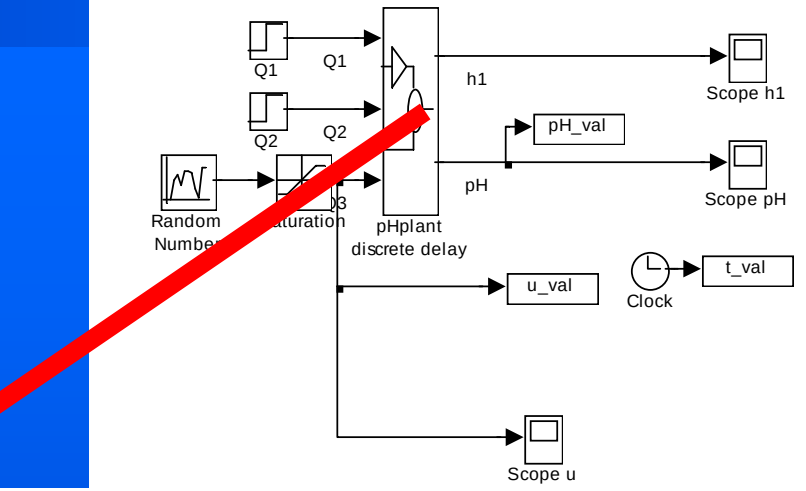
$$p(x) = \left[\frac{1}{A_1 x_3}(W_{a2} - x_1) \;\; \frac{1}{A_1 x_3}(W_{b2} - x_2) \;\; \frac{1}{A_1} \right]^T$$

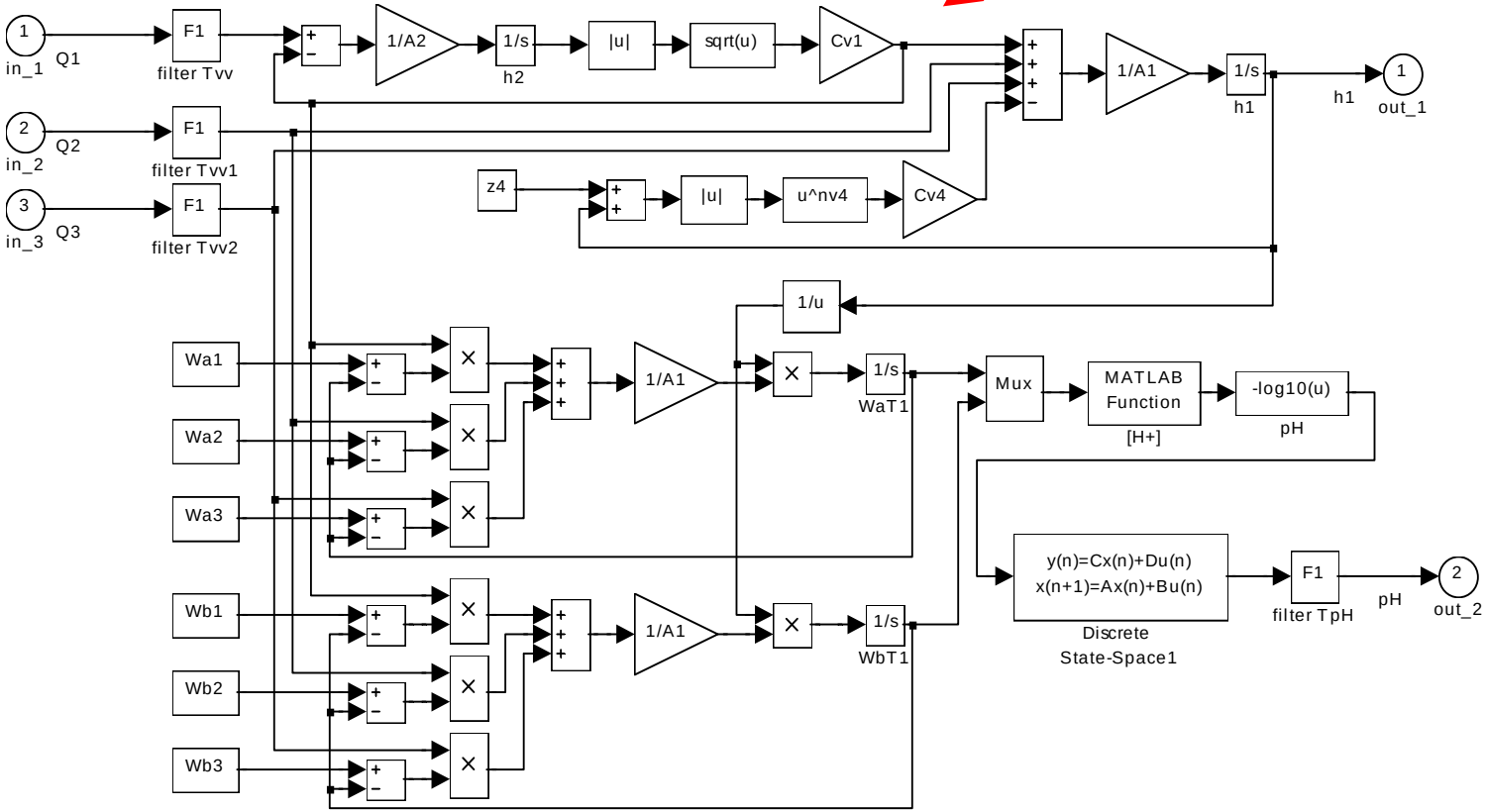
$$c(x, y) = x_1 + 10^{y-14} - 10^{-y} + x_2 \frac{1 + 2 \times 10^{y - pK_2}}{1 + 10^{pK_1 - y} + 10^{y - pK_2}}.$$

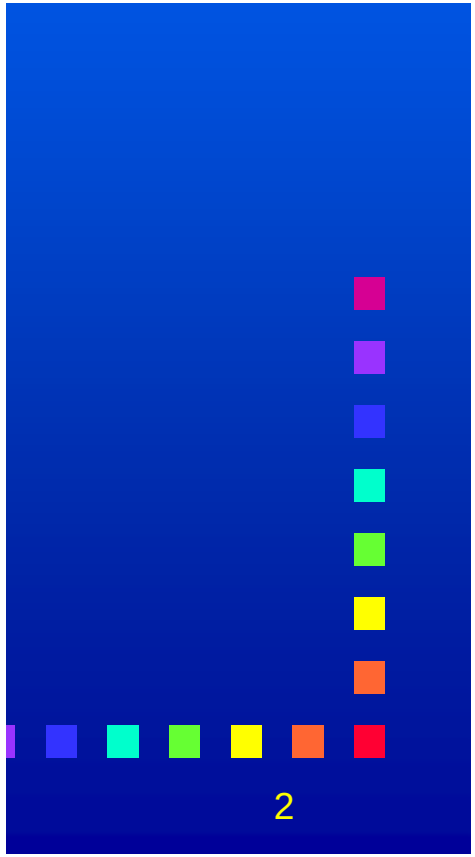
TABLE I
NOMINAL OPERATING CONDITIONS FOR THE pH SYSTEM

$[q_1]$ = 0.003 M HNO_3	q_1 = 16.6 ml/s
$[q_2]$ = 0.03 M $NaHCO_3$	q_2 = 0.55 ml/s
$[q_3]$ = 0.003 M NaOH,	q_3 = 15.6 ml/s
0.0005 M $NaHCO_3$	q_{1a} = 16.6 ml/s
A_1 = 207 cm^2	q_4 = 32.8 ml/s
A_2 = 42 cm^2	W_{a1} = 3.00 x 10^{-3} M
z = 11.5 cm	W_{b1} = 0 M
n = 0.607	W_{a2} = -0.03 M
K_{a1} = 4.47 x 10^{-7}	W_{b2} = 0.03 M
K_{a2} = 5.62 x 10^{-11}	W_{a3} = -3.05 x 10^{-3} M
K_w = 1.00 x 10^{-14}	W_{b3} = 5.00 x 10^{-5} M
M = 15.0 s	h_1 = 14.0 cm
Δt_s = 1.0 s	h_2 = 3.0 cm
τ_{pH} = 15.0 s	W_{a4} = -4.32 x 10^{-4} M
τ_h = 15.0 s	W_{b4} = 5.28 x 10^{-4} M
τ_v = 6.0 s	pH = 7.0
θ = 20.0 s	

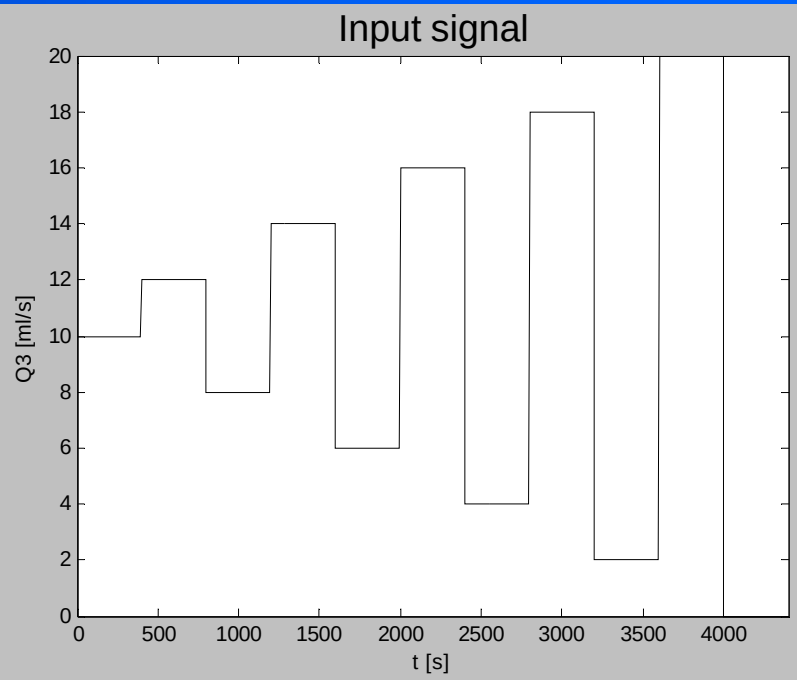
Simulation scheme

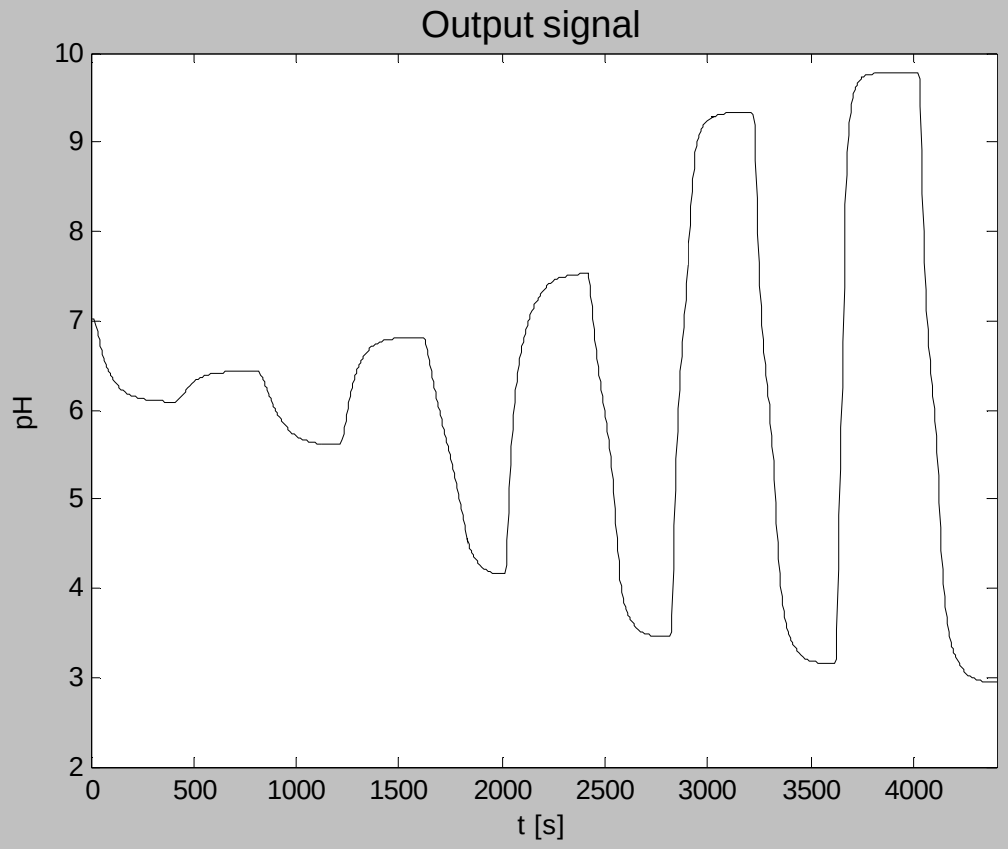






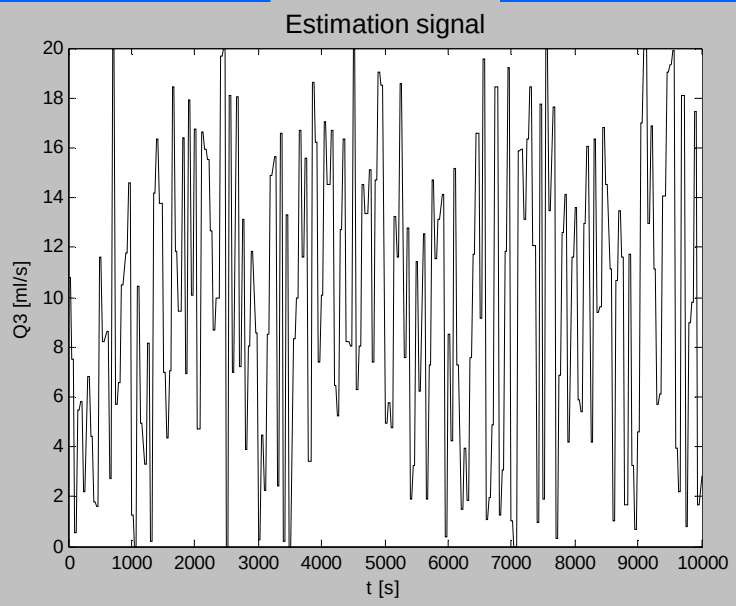
Nonlinearity of the system

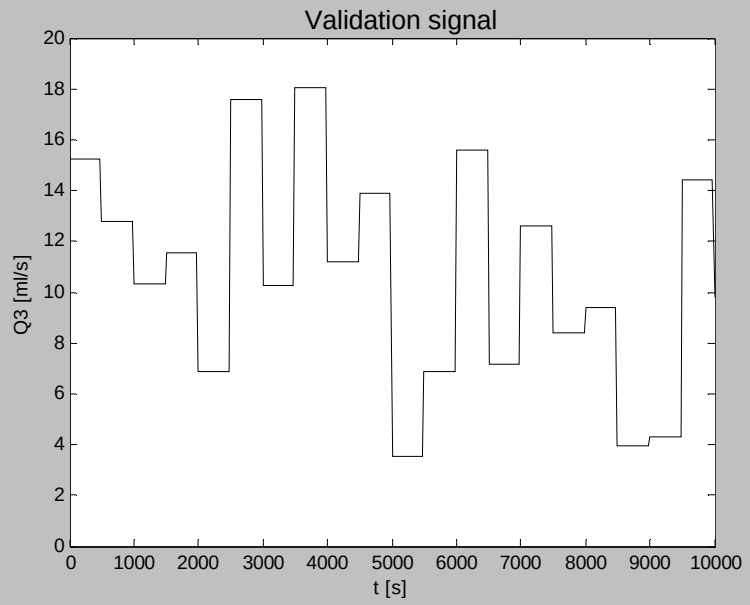


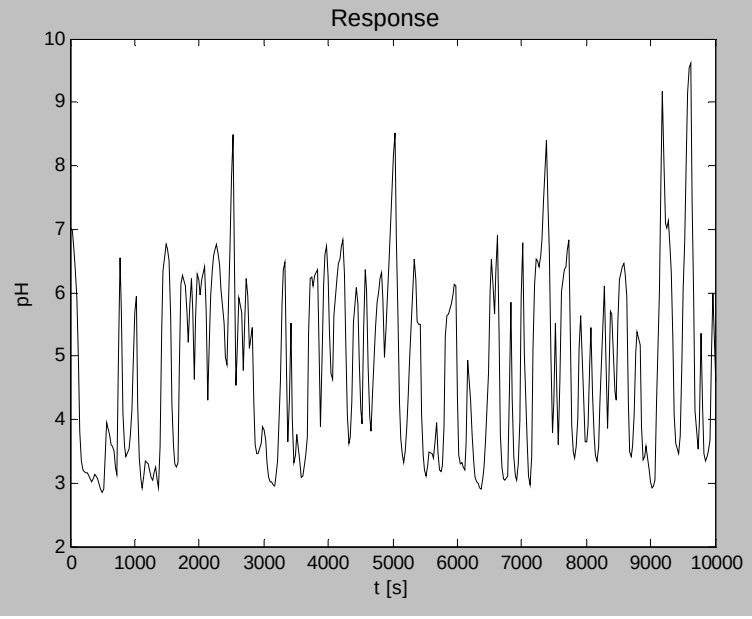


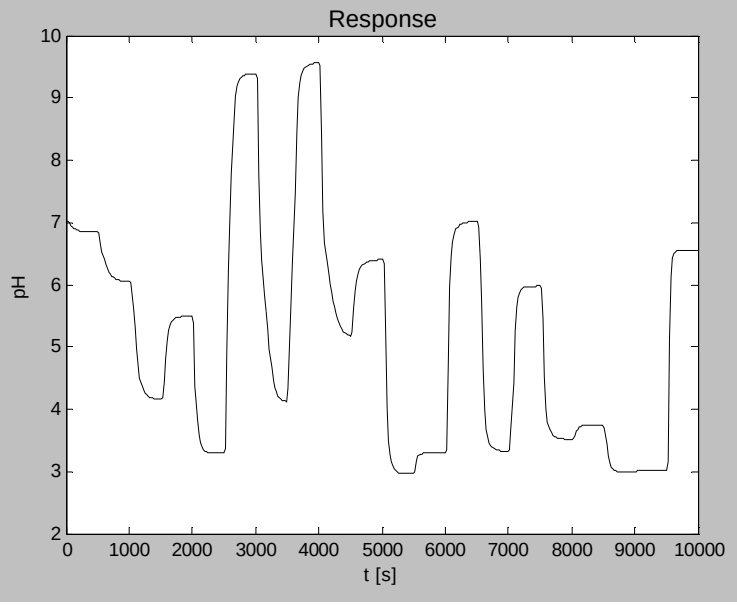
T_s=25 sek

Estimation signal and response
Validation signal and response

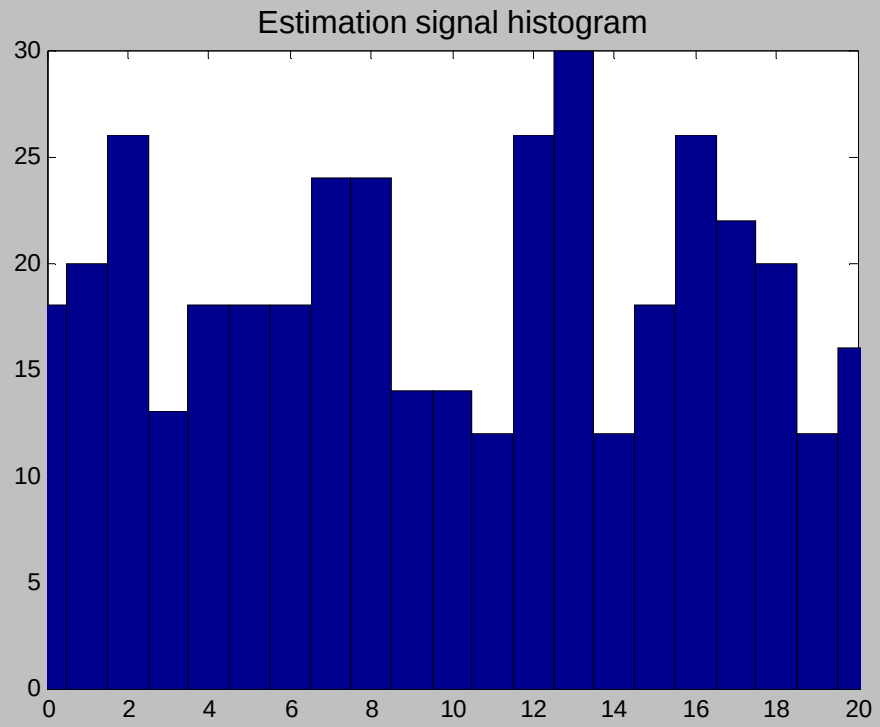


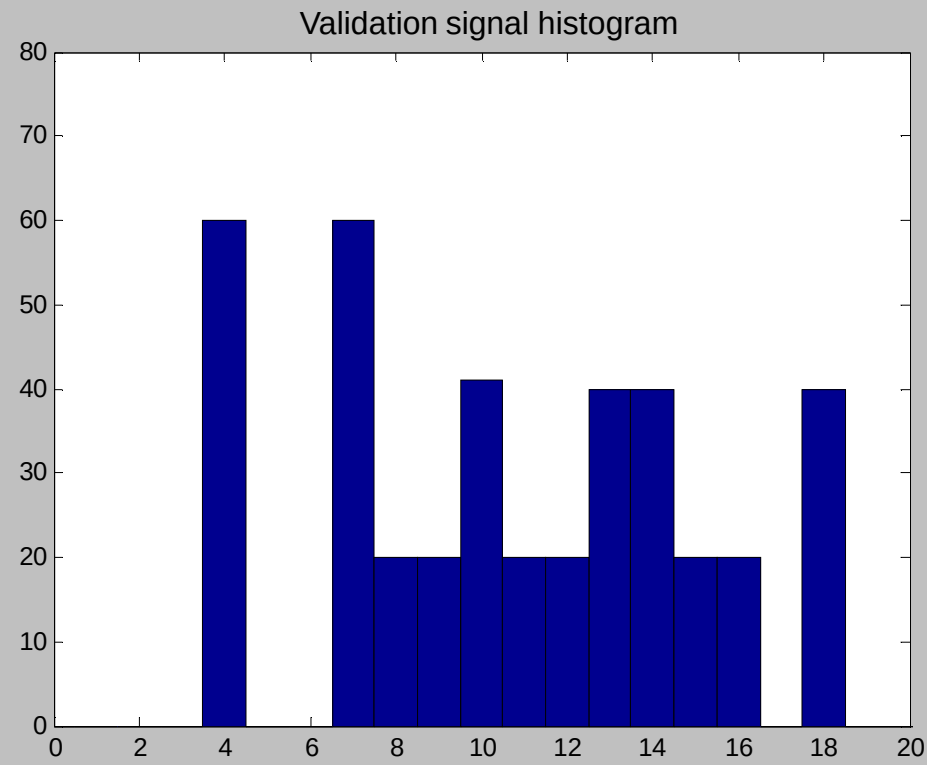




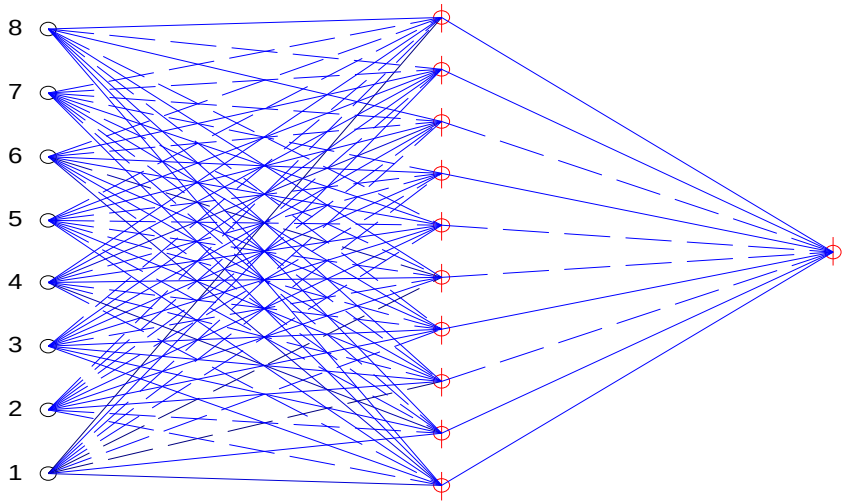


Histograms of magnitudes and input/output data





Neural network, regressors, structure and parameters



Used software:
NNSYSID Toolbox for Matlab

Regressors:
y(k-1), y(k-2), y(k-3), y(k-4),
u(k-1), u(k-2), u(k-3), u(k-4)

Structure:
ARX (model error method)

Optimisation method:
Levenberg-Marquardt
+ pruning

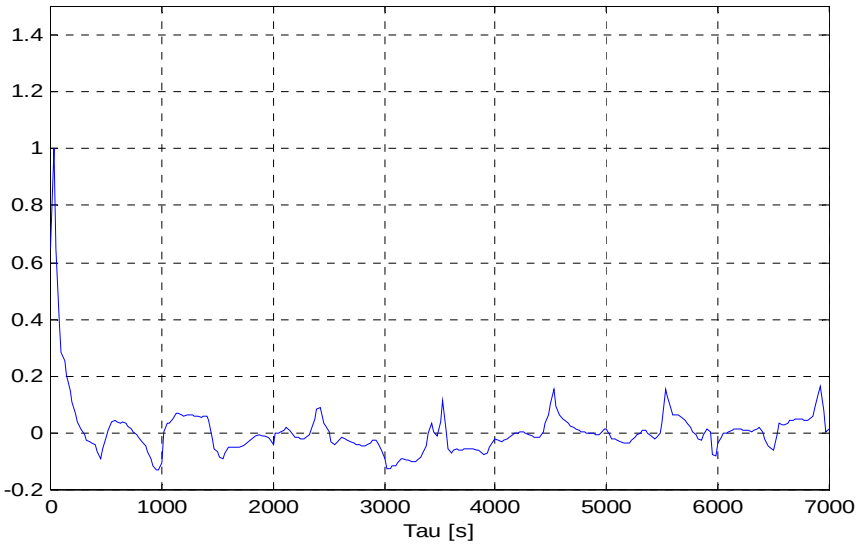
$W_1 =$

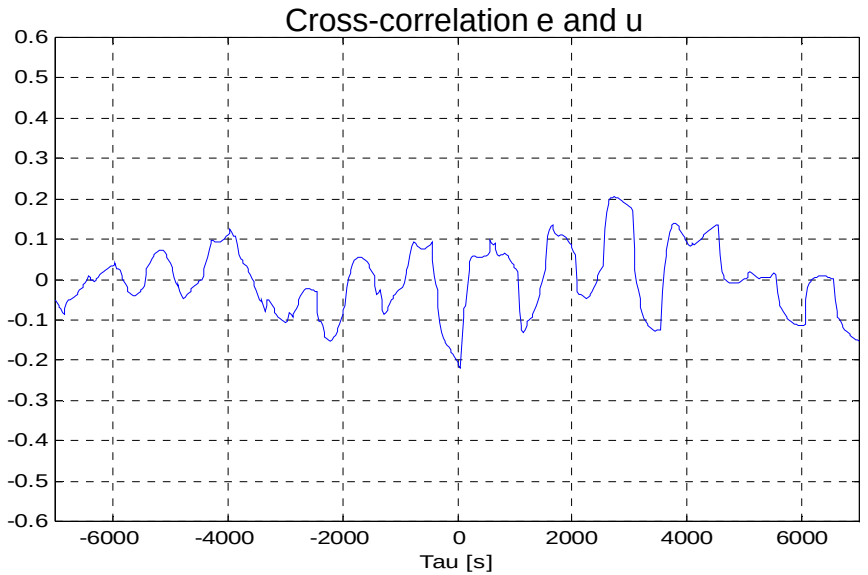
0.5988	-0.2357	0.1720	-0.0748	0.0214	0.1540	0.0213	0.0179	-7.4970
0.0022	-0.1192	0.0549	0.8622	-0.0001	-0.0534	-0.0224	0.0504	-2.9698
–1.3009	0.0314	0.3172	-0.1124	0.0014	0.0284	-0.0005	0.0023	3.1836
–0.2204	0.0543	0.2596	-0.0060	-0.0377	0.0066	0.0629	-0.0284	-0.3709
–1.0563	0.1834	-0.0253	0.0511	-0.0415	-0.2373	-0.0690	0.0049	7.7772
–0.2920	0.1191	0.1284	0.0604	-0.0270	0.0570	0.0512	-0.0298	-0.6212
–0.1384	-0.0808	0.1015	-0.2309	-0.0010	0.0443	-0.0062	0	0.9345
–0.0594	-0.1937	0.2562	0.6273	0.0164	-0.0161	-0.0083	0.0267	-2.5452
0.0027	-0.0209	0.0412	0.2480	0.0255	0.0108	-0.0072	-0.0009	-1.0742
1.1932	-0.0967	-0.3171	0.1721	-0.0105	-0.0026	-0.0279	0.0240	-5.7575

$W_2 =$

1.6135	0.8473	- 0.8772	1.1552	- 0.7503	- 0.8806
1.9716	- 1.1852	1.9206	0.8306	6.1722	

Simulation residuals validation





This is not a result from nnvalid function!

Model response and original system's response on validation data (simulation, not one-step-ahead prediction)