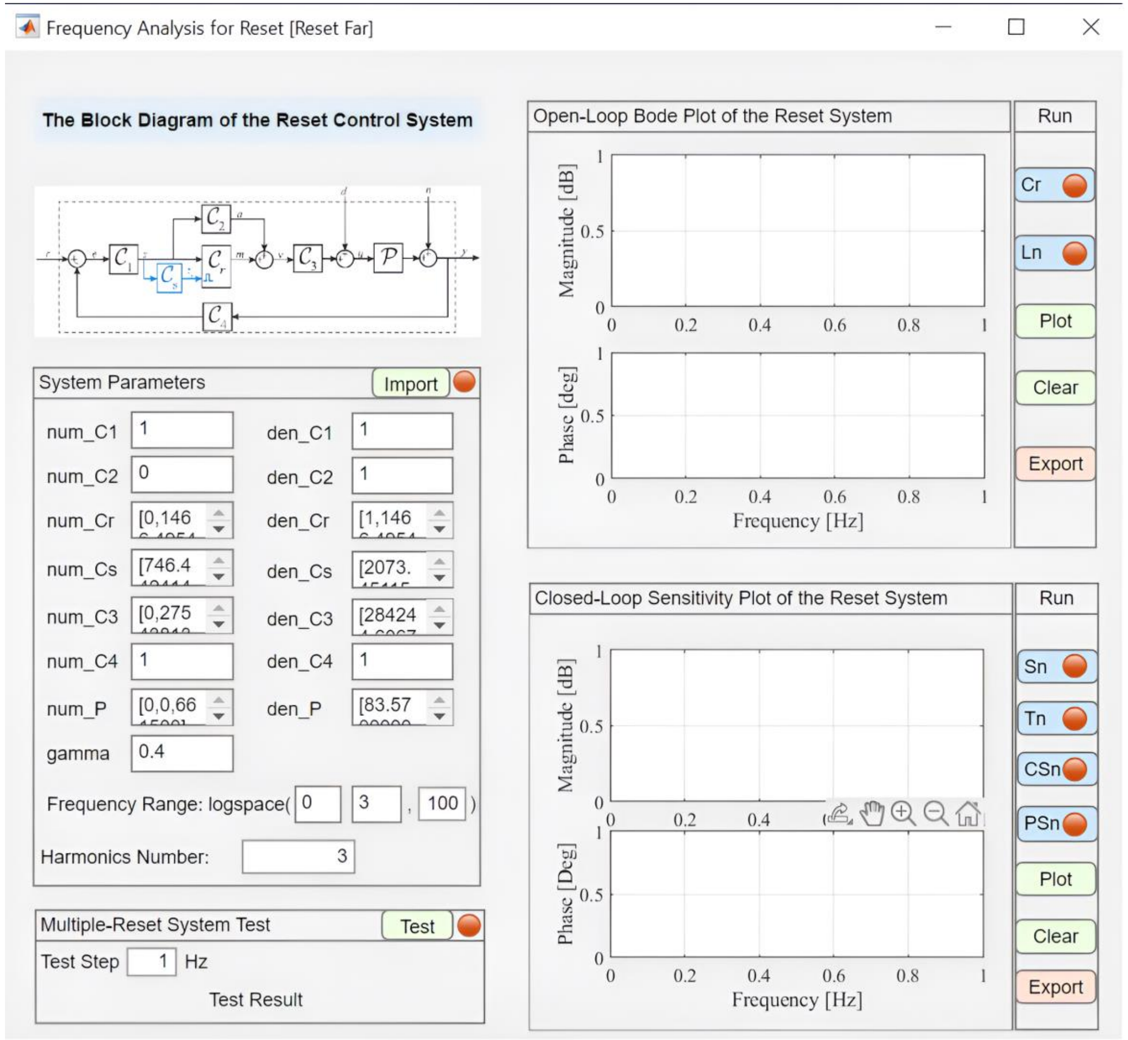
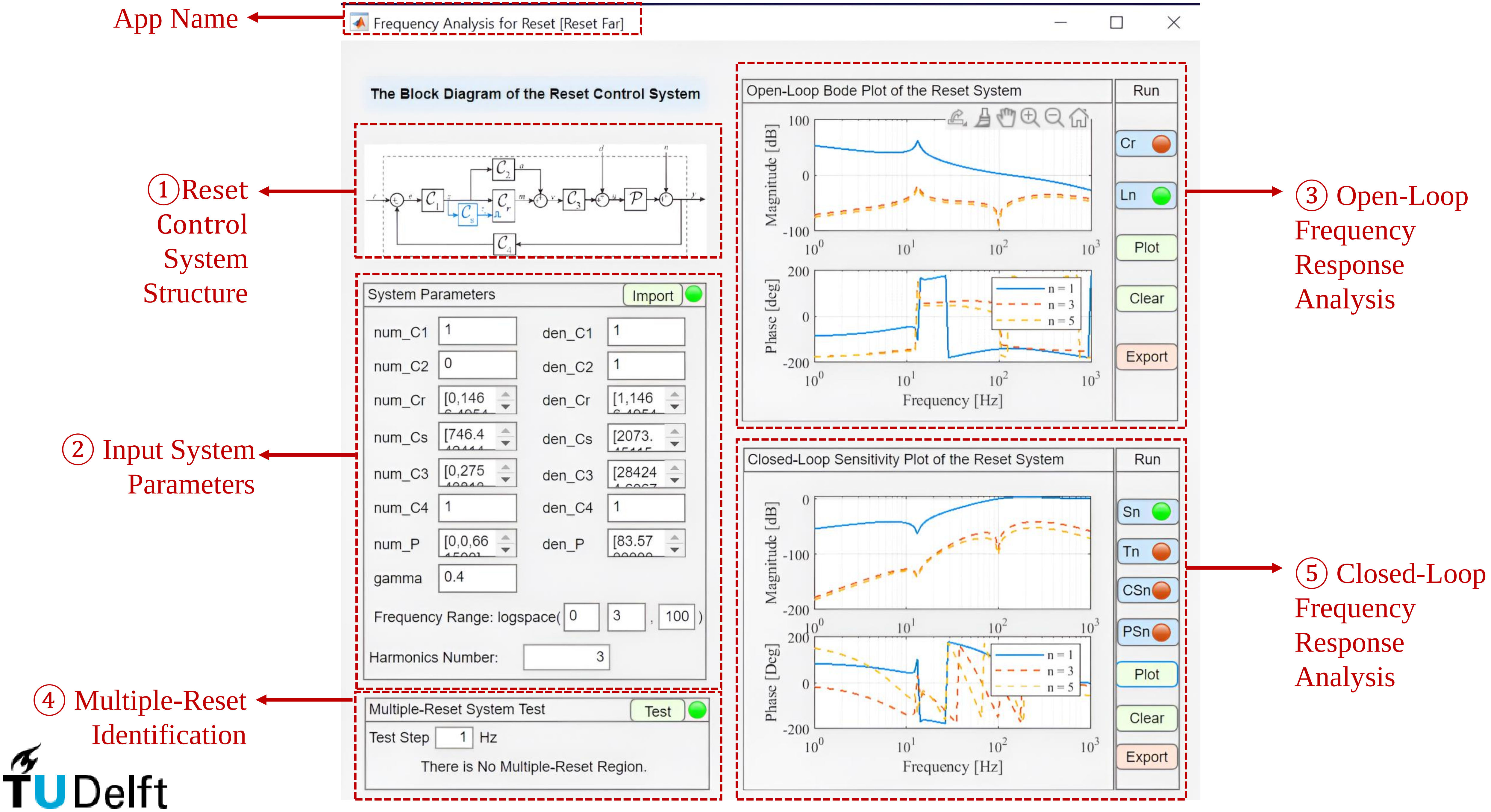
Frequency Response Analysis App for Open-Loop and Closed-Loop Single-Reset-State Reset Control Systems: “Reset Far”



This App is accessible via [https://surfdrive.surf.nl/files/index.php/s/ytIcuh94QQjpVC2]



App Name
Frequency Analysis for Reset [Reset Far]
The Block Diagram of the Reset Control System
① Reset Control System Structure
② Input System Parameters
③ Open-Loop Frequency Response Analysis
④ Multiple-Reset Identification
⑤ Closed-Loop Frequency Response Analysis
System Parameters
Import
num_C1
1
den_C1
1
num_C2
0
den_C2
1
num_Cr
[0,146
den_Cr
[1,146
num_Cs
[746.4
den_Cs
[2073.
num_C3
[0,275
den_C3
[28424
num_C4
1
den_C4
1
num_P
[0,0,66
den_P
[83.57
gamma
0.4
Frequency Range: logspace(
0
3
100
)
Harmonics Number:
3
Multiple-Reset System Test
Test
Test Step
1
Hz
There is No Multiple-Reset Region.
Open-Loop Bode Plot of the Reset System
Run
Cr
Ln
Plot
Clear
Export
Magnitude [dB]
Phase [deg]
Frequency [Hz]
n = 1
n = 3
n = 5
Closed-Loop Sensitivity Plot of the Reset System
Sn
Tn
CSn
PSn
Magnitude [dB]
Phase [Deg]
Frequency [Hz]
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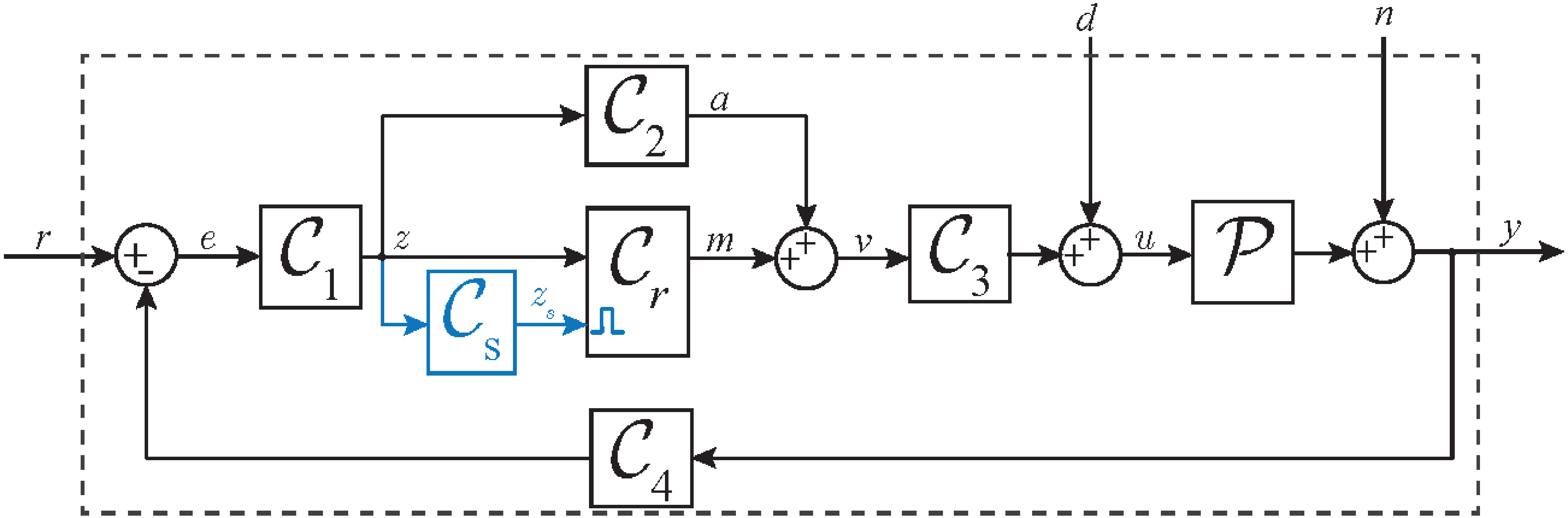
Instructions for the “Reset Far” App

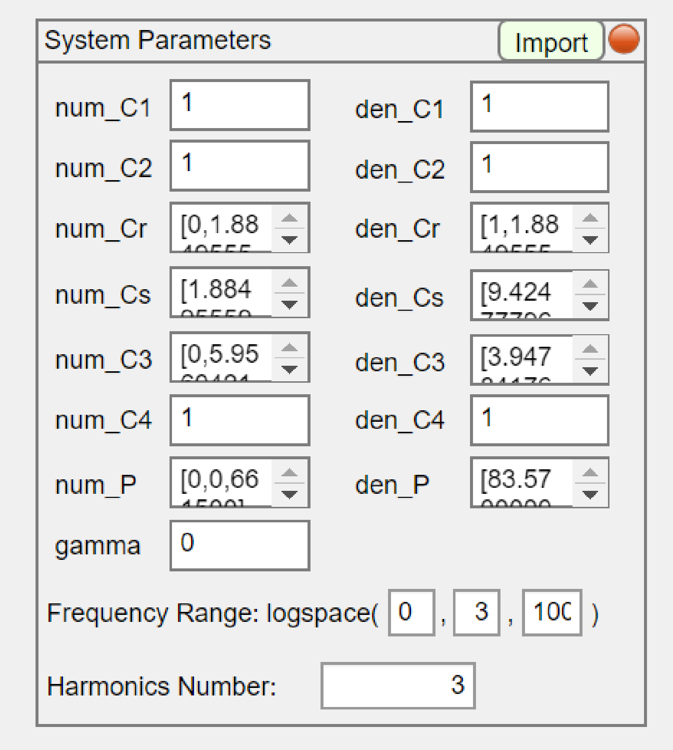
1. System Design: Design a reset control system within the below block diagram of the reset feedback control system.



Instructions for the "Reset Far" App

2. Input the system parameters to the Panel "**System Parameters**", including:

1) The numerators and denominators of $C_1, C_2, C_3, C_4, P, C_s, C_r$(entered as the parameters of its base-linear counterpart) with a reset value $\gamma \in (-1,1]$.
2) The working frequency range (using logarithmic spacing): $logspace(a, b, n)$.
3) The number of harmonics $N_\mathrm{h} \in \mathbb{Z}^+$ included in the calculation.
4) Click the "**Import**" button until the lamp turns **green**, indicating that the parameters have been successfully entered.



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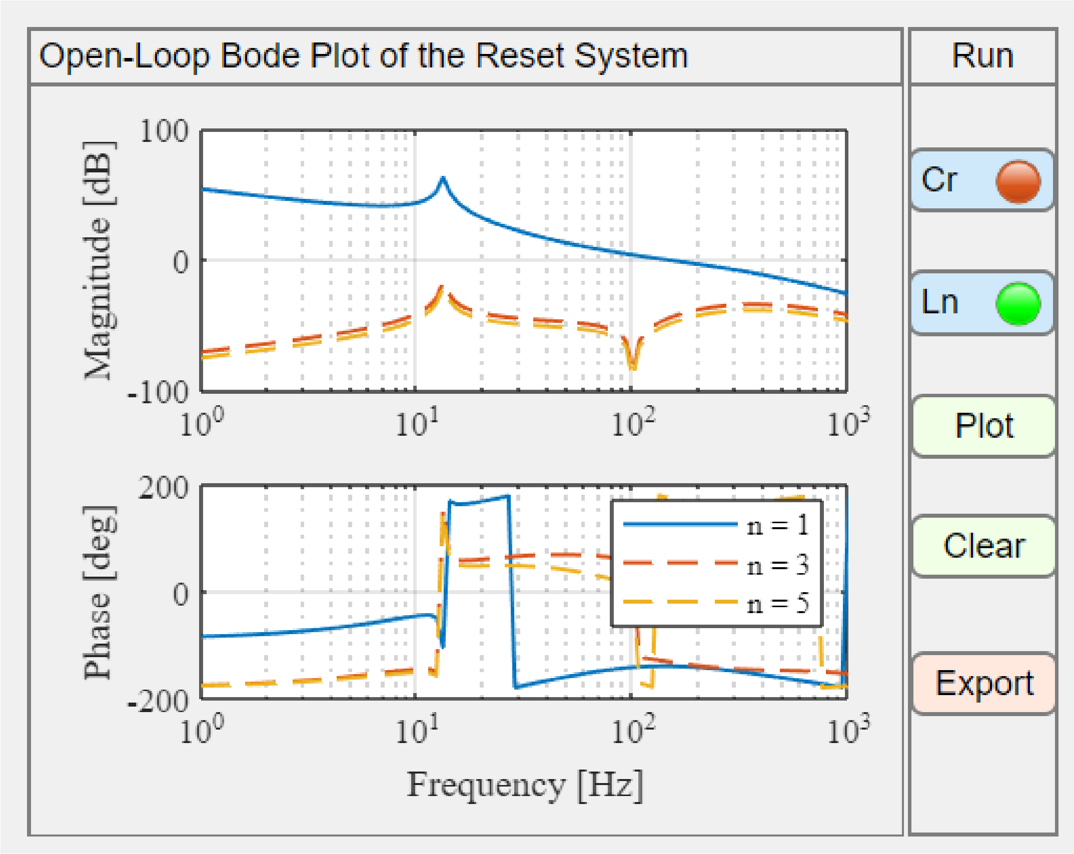
Instructions for the "Reset Far" App

3. **Open-Loop Bode Plot of the Reset System:**

1) Select either "**Cr**" or "**Ln**" until the indicator turns **green.**
2) Click the "**Plot**" to generate the Bode plot of the Higher-Order Sinusoidal Input Describing Function (HOSIDF) for the reset controller C_{r} or the open-loop system L_{n} , as outlined in Theorem 1 of the attached paper.
3) To clear the plot in the axis, click the "**Clear**" button.
4) To export the HOSIDF data, click the "**Export**" button, and the data will be sent to the workspace.



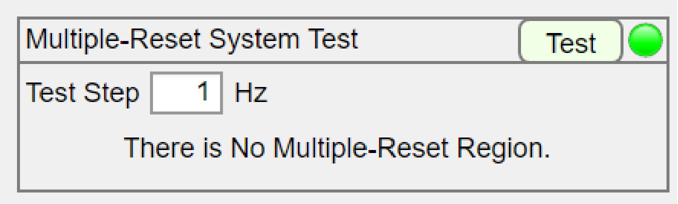
4. **Multiple-Reset System Test** before Closed-Loop Analysis:

This panel identifies the frequency range where the sinusoidal-input closed-loop reset control system exhibits multiple (more than two) reset instants per steady-state cycle based on the method in [1]. In this range, the accuracy of the Sinusoidal-Input Describing Function (SIDF) analysis will be compromised.

To use it, click the "**Test**" button, which turns **green** when active, and select the sweeping step size, defaulting to 1 Hz. The output will indicate two possible scenarios:

1) *There is No Multiple-Reset Region*, meaning the system operates with only two reset instants per cycle across the tested frequency range.
2) *Multiple-Reset Regions: f_α to f_β* [Hz], showing the frequency range(s) where multiple resets occur, with (f_α, f_β) as the boundaries.

If multiple-reset regions are detected, subsequent closed-loop HOSIDF analysis may yield inaccuracies, and adjusting system design parameters is recommended until *There is No Multiple-Reset Region* is achieved.

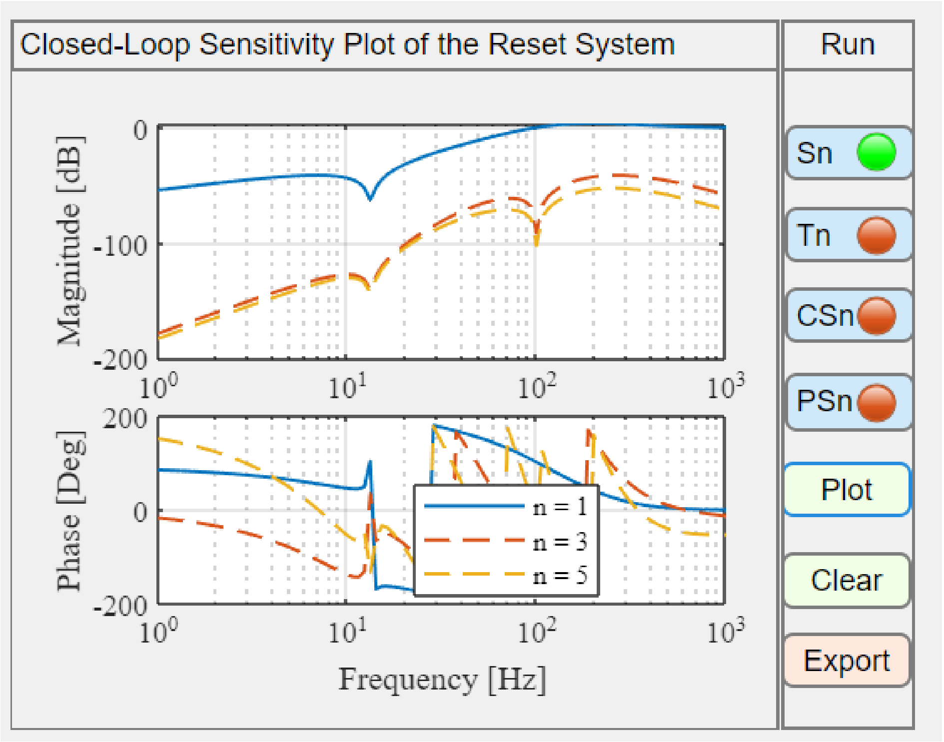


[1] *Xinxin Zhang and S. Hassan HosseinNia. Enhancing the reliability of closed-loop describing function analysis for reset control applied to precision motion systems. https://arxiv.org/abs/2412.00502.*

Instructions for the “Reset Far” App

5. **Closed-Loop Bode Plot of the Reset System:**

1) Select either S_n or T_n, CS_n, or PS_n until the indicator turns **green**.
2) Click the “**Plot**” to generate the Bode plot of the sensitivity functions, complementary sensitivity functions, control sensitivity functions, and process sensitivity functions of the closed-loop reset systems, as outlined in Theorem 2 and Corollary 1 of the attached paper.
3) To clear the plot in the axis, click the “**Clear**” button.
4) To export the HOSIDF data, click the “**Export**” button, and the data will be sent to the workspace.



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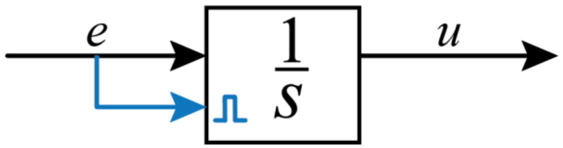
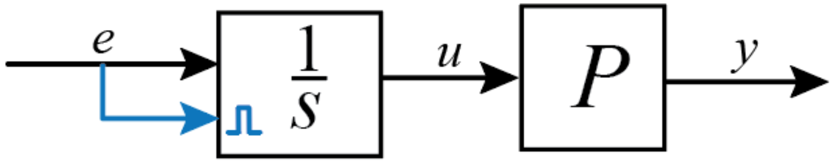
Examples for Using the "Reset Far" App

In the "Examples" folder, parameters of three examples for using the "Reset Far" App are provided.

Example 1: Only a single Clegg Integrator (CI) with γ=0 in the system, where the blue lines represents reset actions.



Example 2: A Clegg Integrator (CI) with γ=0 as the conrtoller and a Mass-Spring-Damper (MSD) system as the plant P.



$$P = \frac{6.615 \times 10^5}{83.57s^2 + 279.4s + 5.837 \times 10^5}$$

Example 3 is the case study presented in the paper "Higher-Order Sinusoidal Input Describing Functions for Open-Loop and Closed-Loop Reset Control with Applications to Mechatronics Systems" (currently submitted and not yet publicly available). This example will be demonstrated in detail in the following slides. Readers can explore other examples as well.

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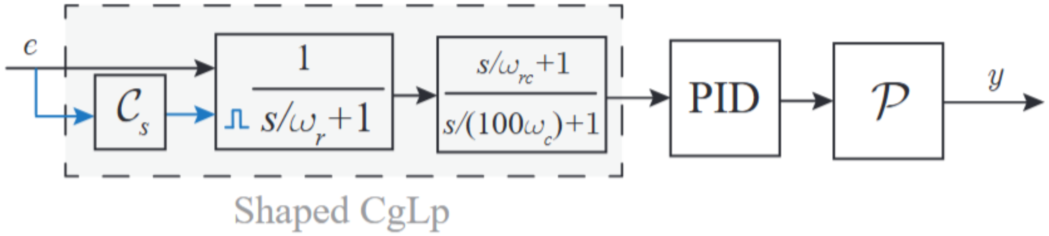
Example 3: Utilizing the MATLAB App “Reset Far” for Frequency-Domain Analysis of Reset Control Systems (in Section 6 in the attached paper)

The open-loop block diagram of a shaped Constant in Gain Lead in Phase (CgLp) [2]-PID control system is shown as below.



The designed system parameters are given by:

$$C_s = \frac{s/660\pi+1}{s/237.6\pi+1}, \text{PID} = k_p\left(1+\frac{\omega_i}{s}\right)\left(\frac{s/\omega_d+1}{s/\omega_t+1}\right)\left(\frac{1}{s/\omega_f+1}\right),\ P = \frac{6.615\times10^5}{83.57s^2+279.4s+5.837\times10^5}, \text{ where}$$

$$\omega_r = 466.8\pi,\ \ \omega_d = 120\pi,\quad k_p = 35.7,$$

$$\omega_{rc} = 216\pi,\quad \omega_t = 480\pi,$$

$$\omega_c = 240\pi,\quad \omega_f = 2400\pi.$$

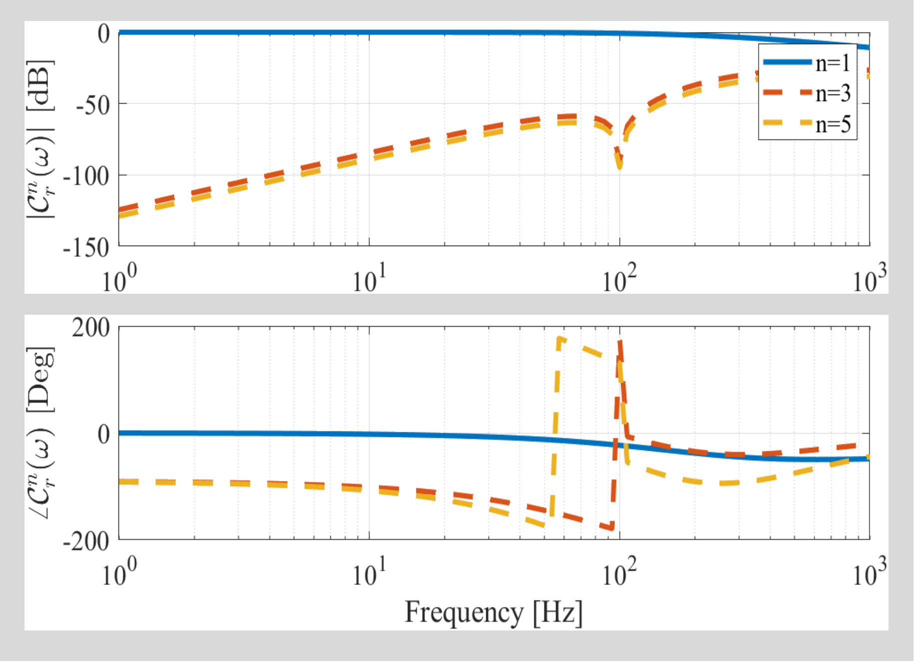
[2] *Saikumar, Niranjan, Rahul Kumar Sinha, and S. Hassan HosseinNia. "“Constant in Gain Lead in Phase” element–application in precision motion control." IEEE/ASME Transactions on Mechatronics 24.3 (2019): 1176-1185.*

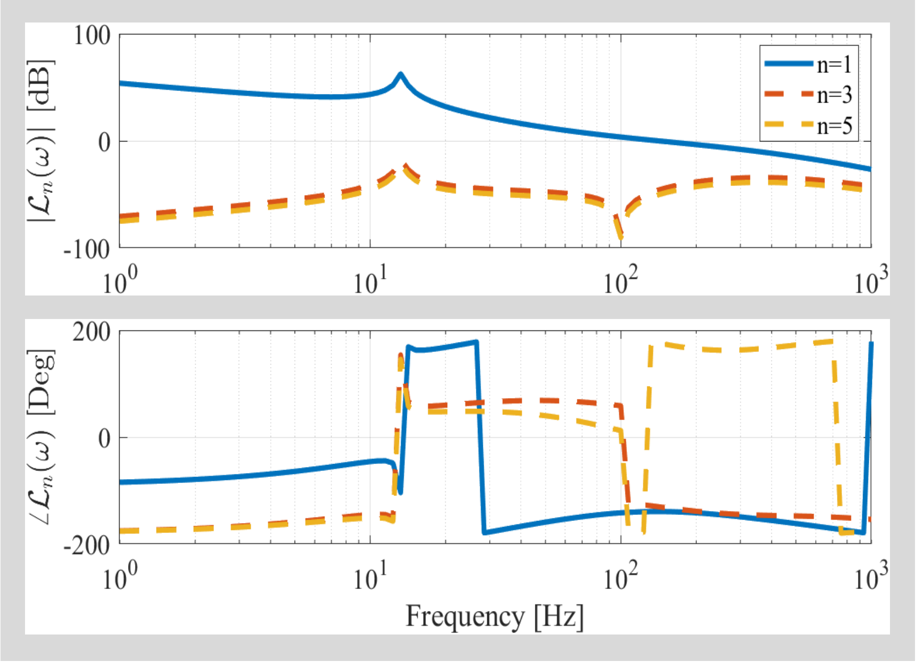
1. Input the following information to the System Parameters Panel and Click Import:

- [num_C1, den_C1] = [1,1];
- [num_C4, den_C4] = [1,1];
- [num_C2, den_C2] = [0,1];
- [num_Cr, den_Cr] = [[0,1466.49545069572], [1,1466.49545069572]];
- [num_Cs, den_Cs] = [[746.442414492935,1547711.88376123],[2073.45115136926,1547711.88376123]];
- [num_C3, den_C3] = [[0,27543813204917.1,3.55355785262087e+16,1.12218251724398e+19,6.55895879471736e+20],[284244.606751373,24003323054.3940,197139791380073,2.43671968654372e+17,0]];
- [num_P, den_P] = [[0,0,661500], [83.5700000000000,279.400000000000,583700]];
- gamma = 0.4;
- Frequency Range: logspace (0,3,1000);
- Harmonics Number: 3.

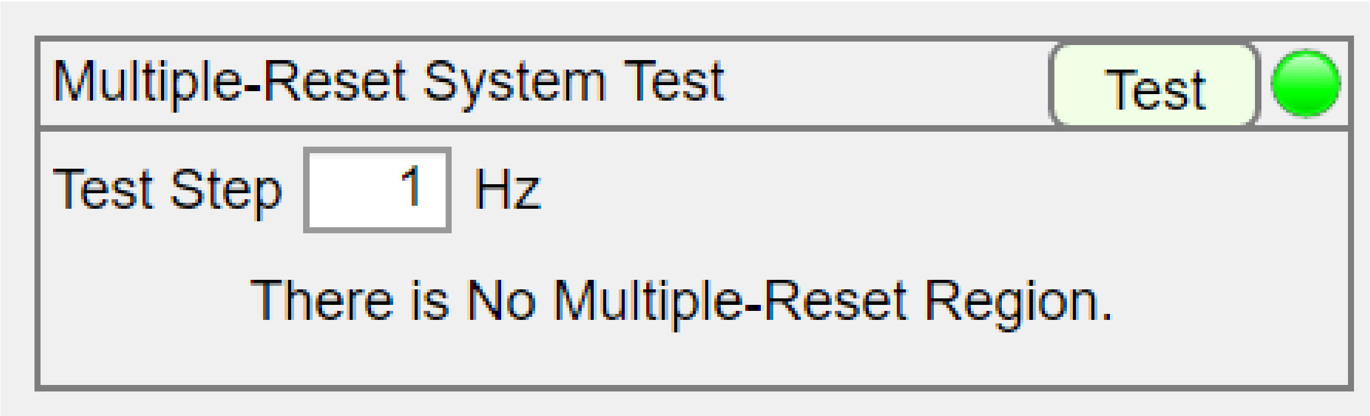
2. Open-Loop HOSIDFs Analysis:

1) Select C_r or L_n to generate the Bode plot of the Higher-Order Sinusoidal Input Describing Functions (HOSIDFs) for the reset controller C_r or the open-loop system, as outlined in Theorem 1 of the attached paper.
2) Click the "Plot" button, the Bode plot for C_r or L_n will be displayed.
3) To export the HOSIDF data, click the "Export" button, and the data will be sent to the workspace.
4) Using the data in the workspace, the figures of C_r or L_n are plotted as shown below.



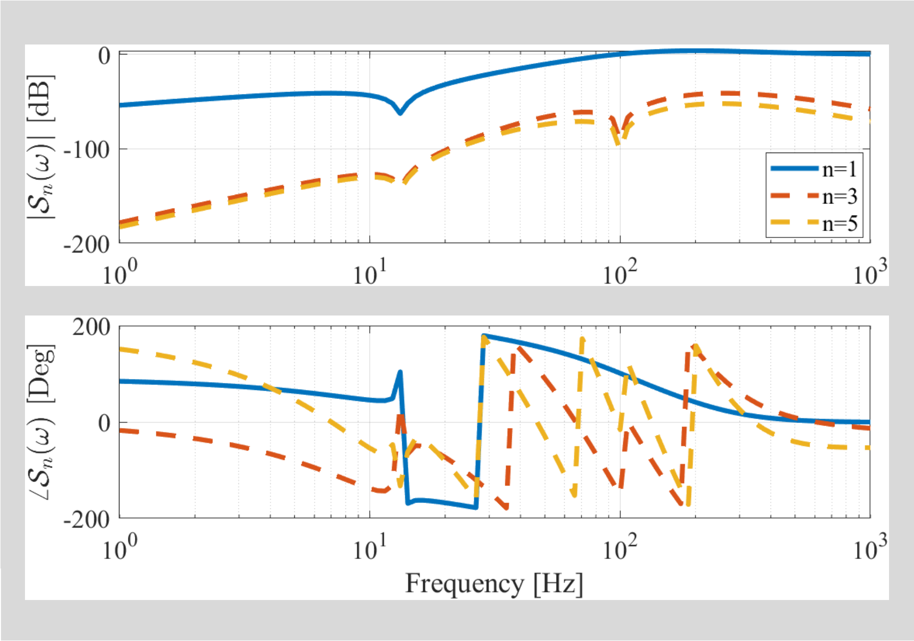


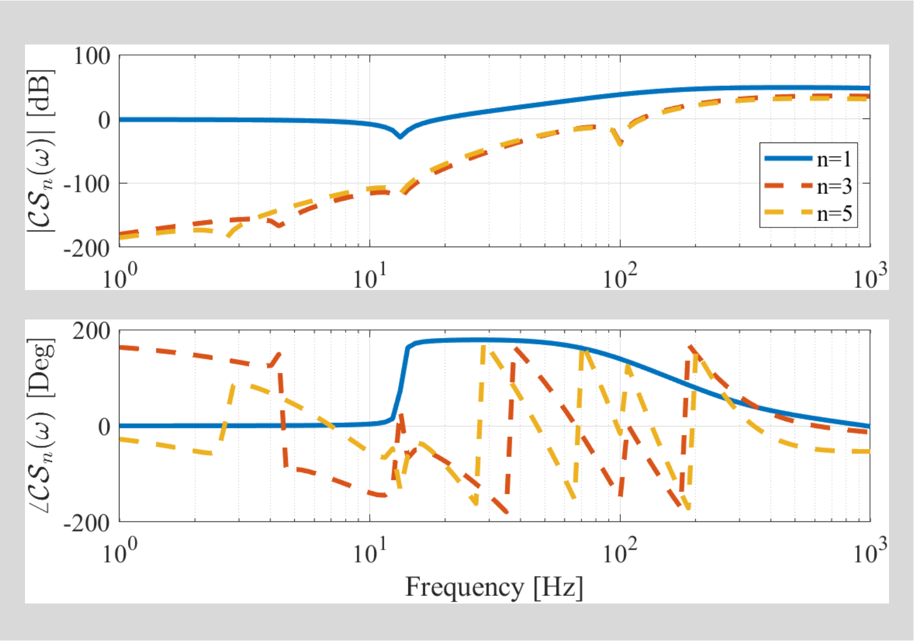
3. Click the “Test” button on the “Multiple-Reset System Region ” panel, and wait the lamp turns green. The block shows “There is No Multiple-Reset Region”.



4. Closed-Loop HOSIDFs Analysis:

1) Select either S_n and CS_n to generate the Bode plots of the sensitivity functions, control sensitivity functions, and process sensitivity functions of the closed-loop reset systems, as outlined in Theorem 2 and Corollary 1 of the attached paper.
2) Click the "Plot" button, the Bode plot will be displayed.
3) To export the HOSIDF data, click the "Export" button, and the data will be sent to the workspace.
4) Using the data in the workspace, the figures of S_n and CS_n are plotted as shown below.





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