ITC 2003

A Generic Test Path and DUT Model for DataCom ATE

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Purposes

- Understand how will a transfer function impact the deterministic jitter (DJ) in a linear system
- Introduce a generic model for quantifying DJ for an I/O path
- Apply the linear system/generic model method to analyze a high-speed ATE path

Outline

- Overview of an ATE high-speed I/O path
- Review of existing analysis methods
- Introducing a generic, pole/zero based model/analysis method
- Simulation results of the new method
- Application of the generic method to ATE high-speed I/O path analysis
- Conclusion

ATE High-Speed I/O Path

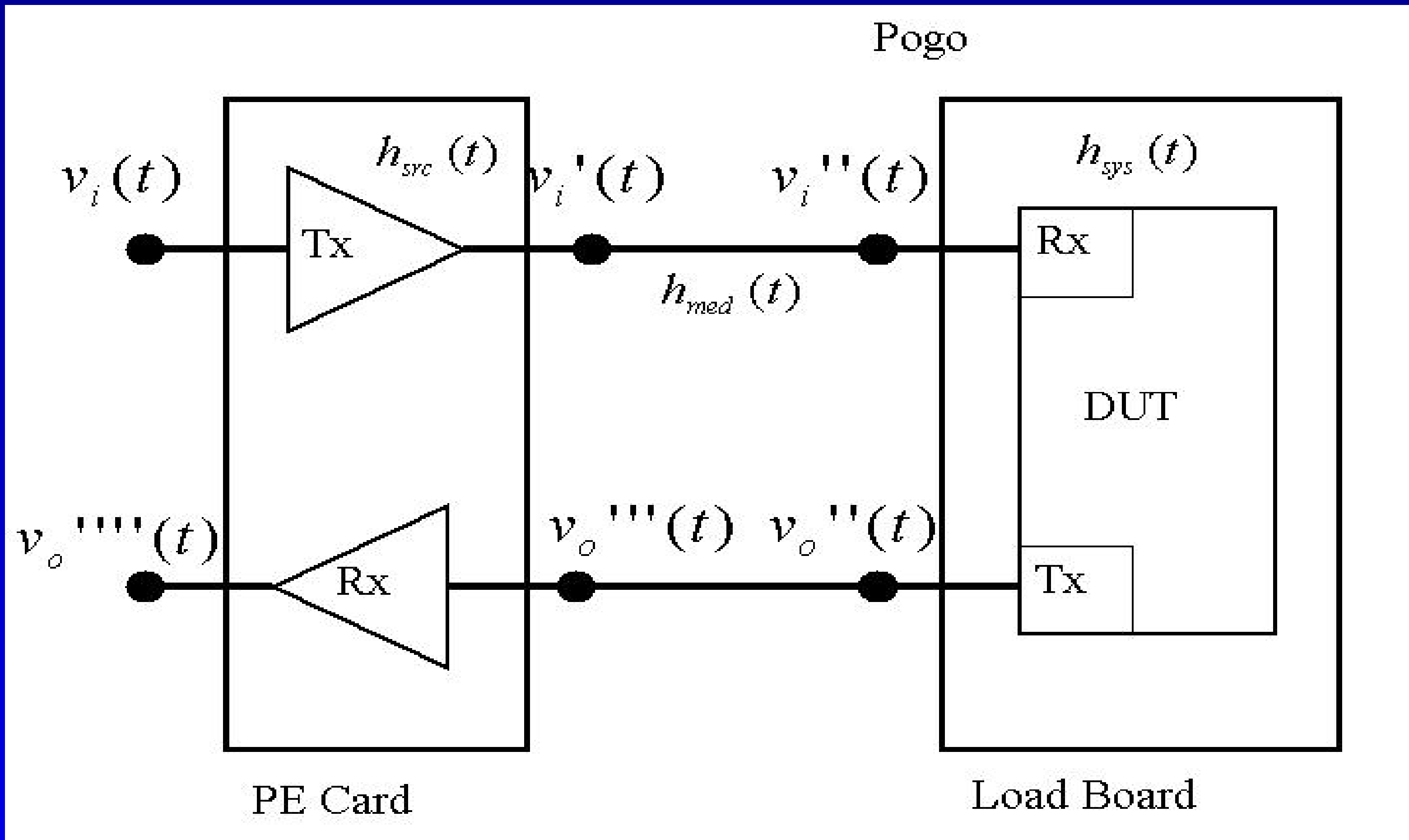
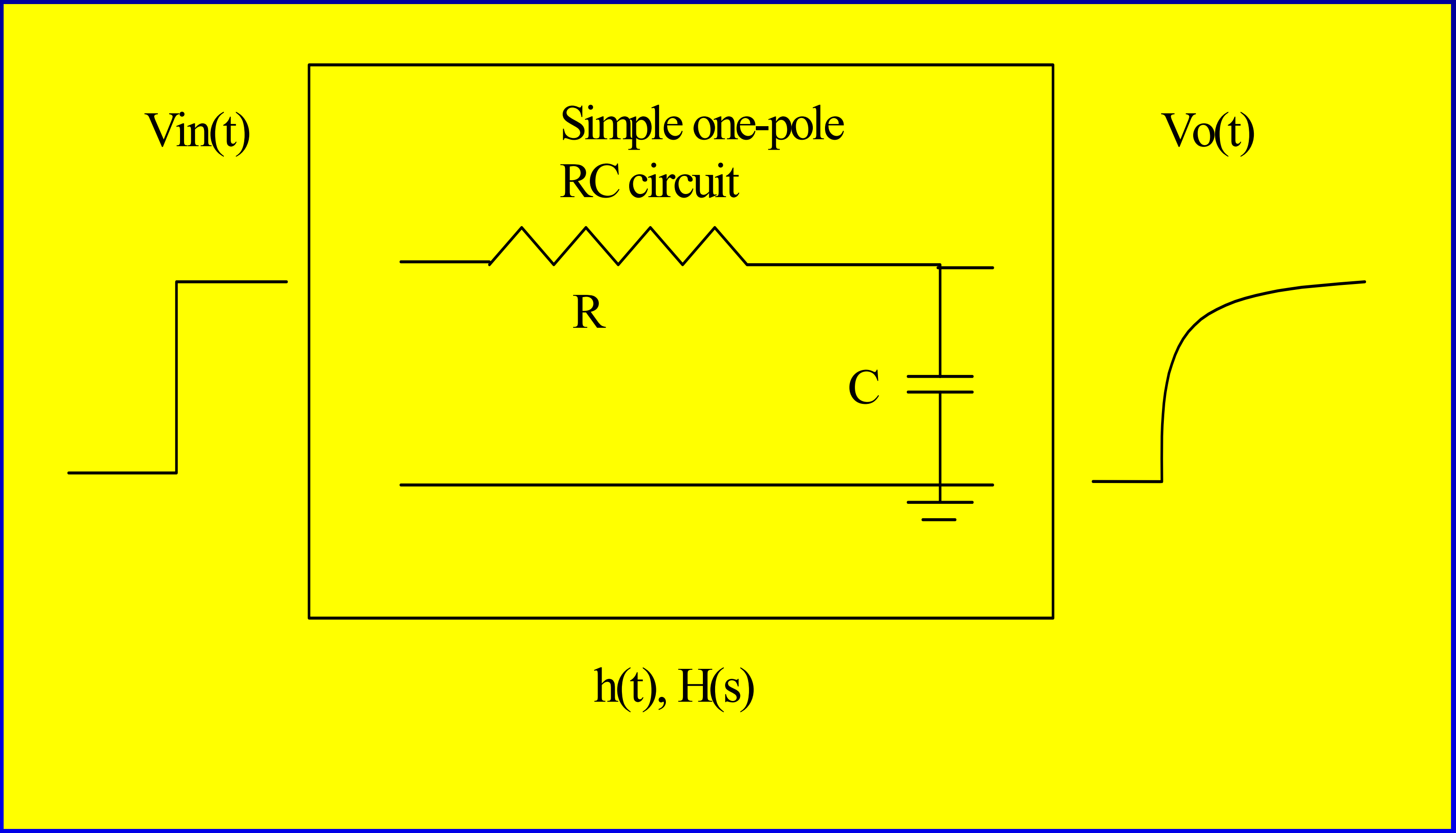


Figure 1. A Typical ATE Setup

Review of A Simple One-Pole System



Limitations of The One-Pole Model

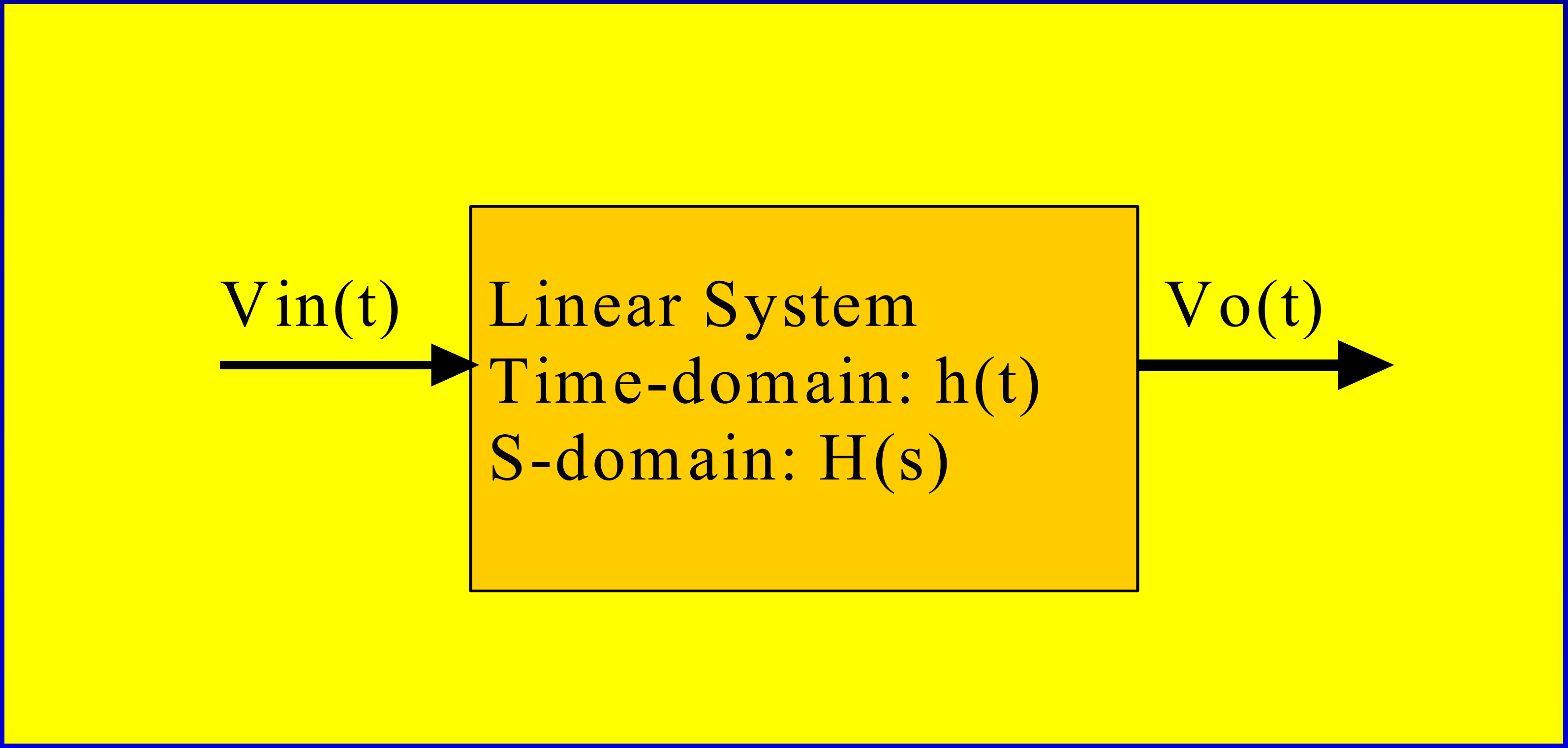
- ***Cannot*** handle dynamical aspects of the step response (I.e., ringing, damping, overshoot, undershoot etc.)
- ***Does not*** emulate most of the high-speed I/O paths
- Amplitude ISI effect is shielded

What is Needed?: A Generic, N-pole, M-Zero Model

Goals:

- Eliminate those limitations for the one-pole 1st-order model
- Scalable and generic
- Comprehensive and accurate

Review of Linear System Theory :



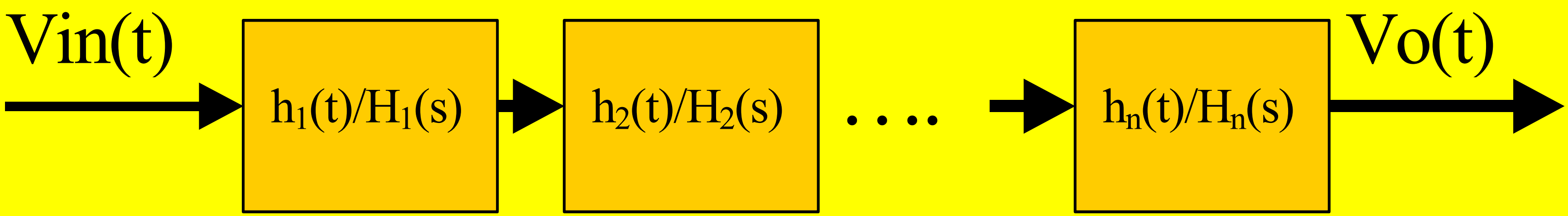
Review of Linear System Theory Cont :

$$H(s) = \int_{-\infty}^{\infty} h(t)e^{-st}\,dt$$

$$V_0(t) = h(t) * V_i(t) = \int_{-\infty}^{\infty} h(\tau)V_i(t-\tau)\,d\tau$$

$$V_0(s) = H(s)V_i(s)$$

ndependent and Cascade Linear System



$$h(t) = h_1(t) * h_2(t) * ..... * h_n(t)$$

$$H(s) = H_1(s) \bullet H_2(s) \bullet ...... \bullet H_n(s)$$

A Generic N-Pole, M-Zero Model

$$H(s) = K \frac{s^{M} + a_{M-1}s^{M-1} + \text{☹} + a_0}{s^{N} + b_{N-1}s^{N-1} + \text{☹} + b_0}$$

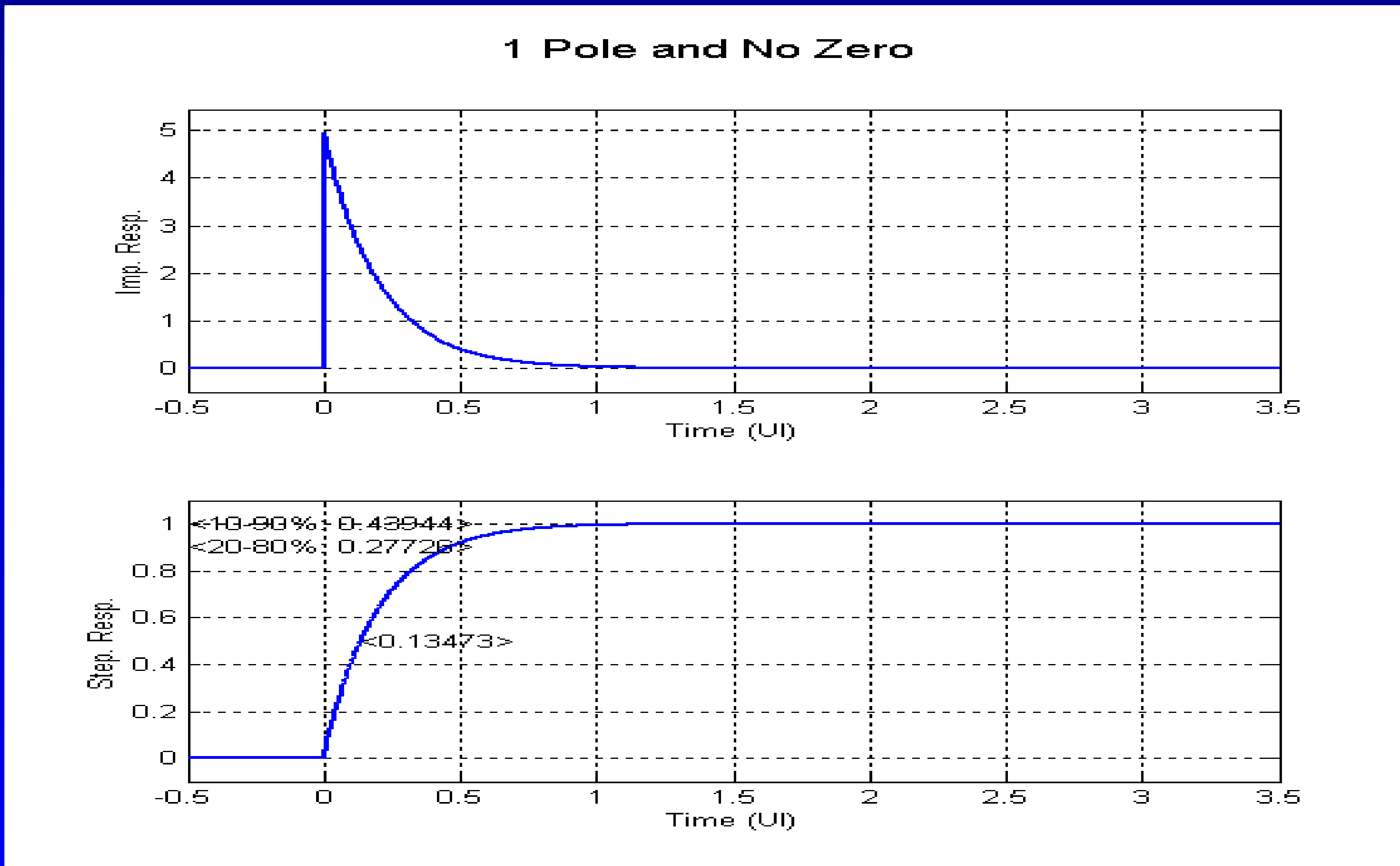
$$= K \frac{\prod_{m=1}^{M} (s + z_m)}{\prod_{n=1}^{N} (s - p_n)}$$

Requirements for A Generic Model

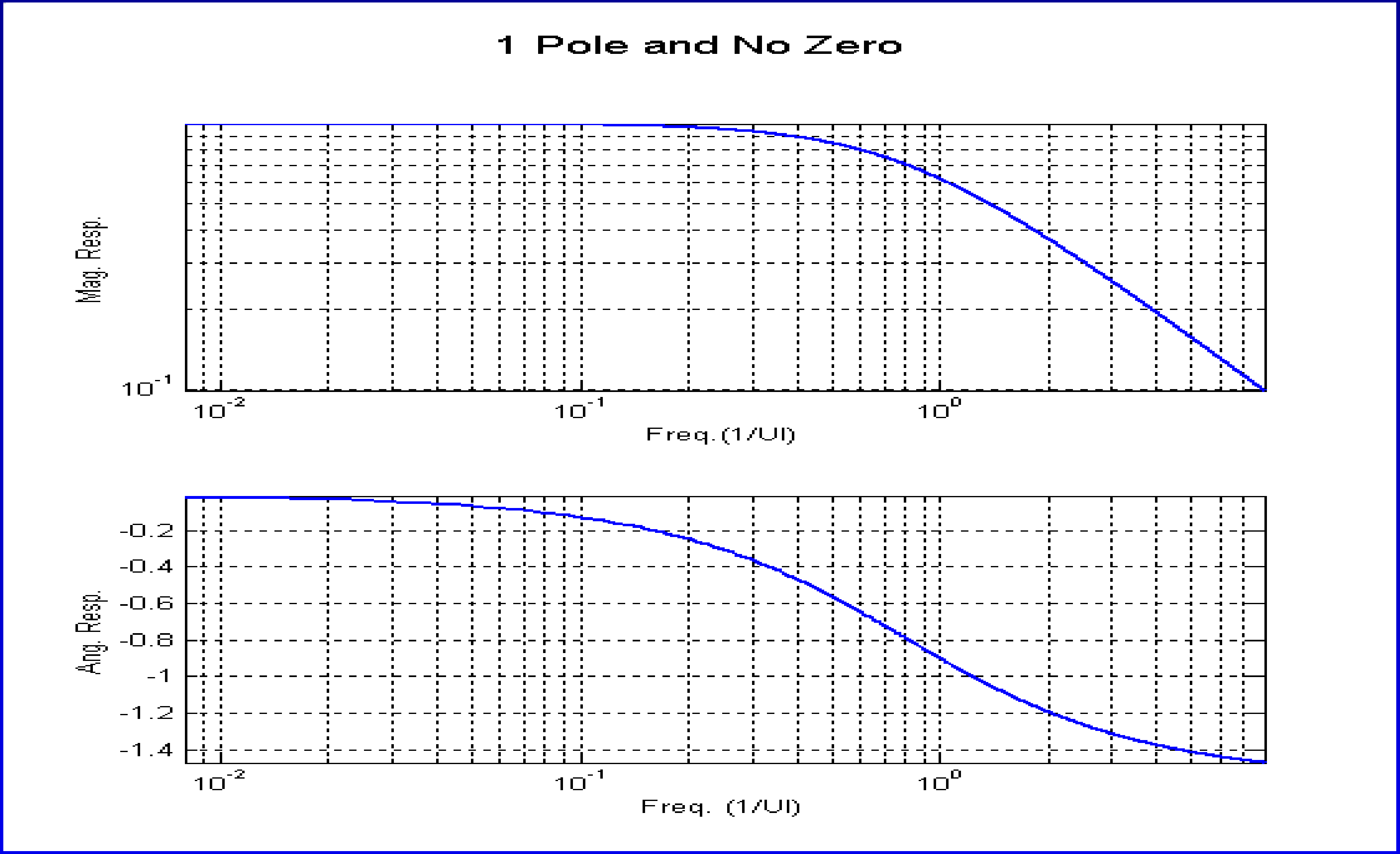
- It must be stable, i.e., all the poles are located on the left half of the *S*-plane, and the number of poles is >= the number of zeros

- It must be causal, i.e., the region of convergence (*ROC*) is right to the rightmost pole

Case Study I: 1-Pole, 0-Zero (Time-domain)

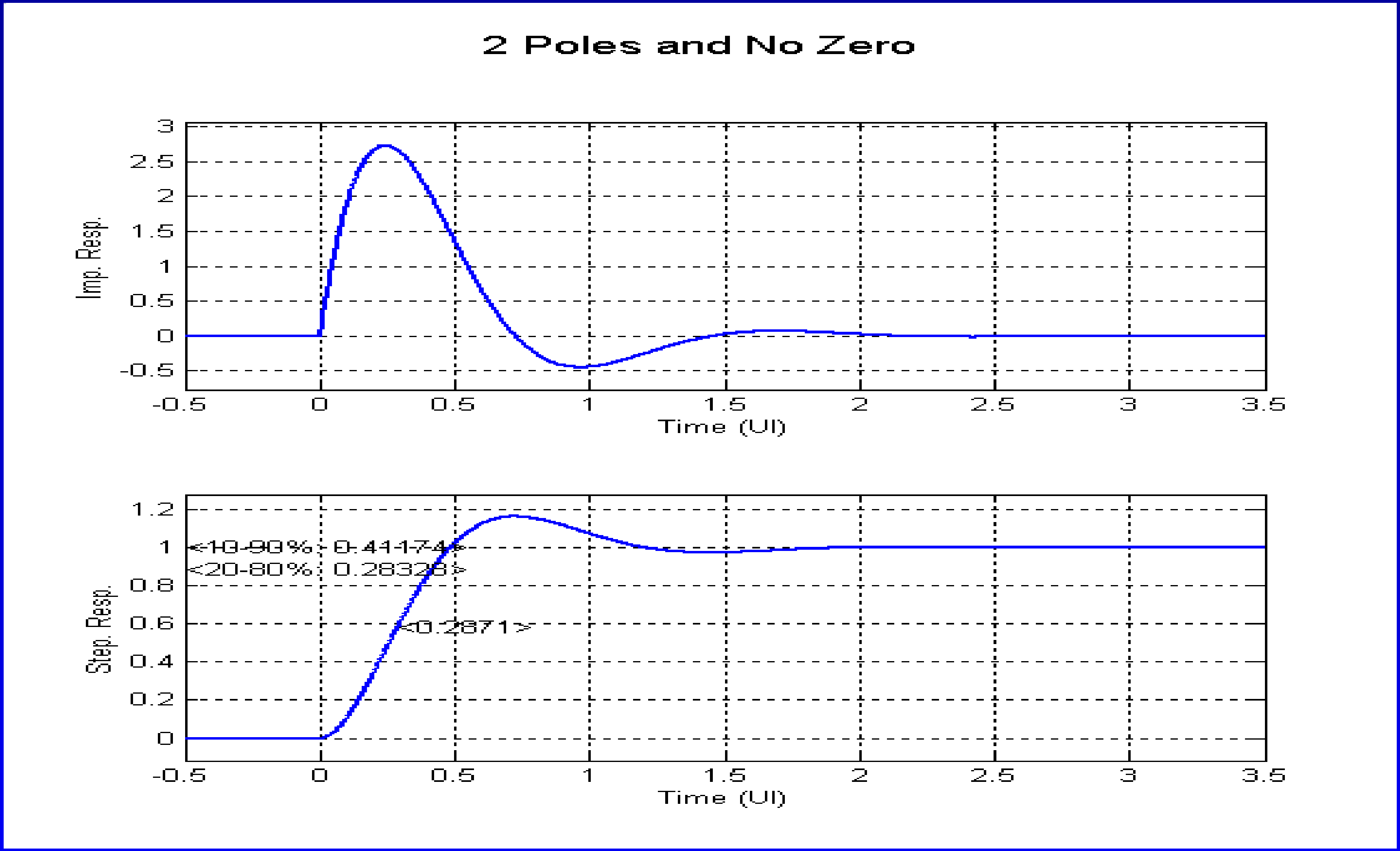


Case Study I: 1-Pole, 0-Zero Cont.. (Frequency-domain)



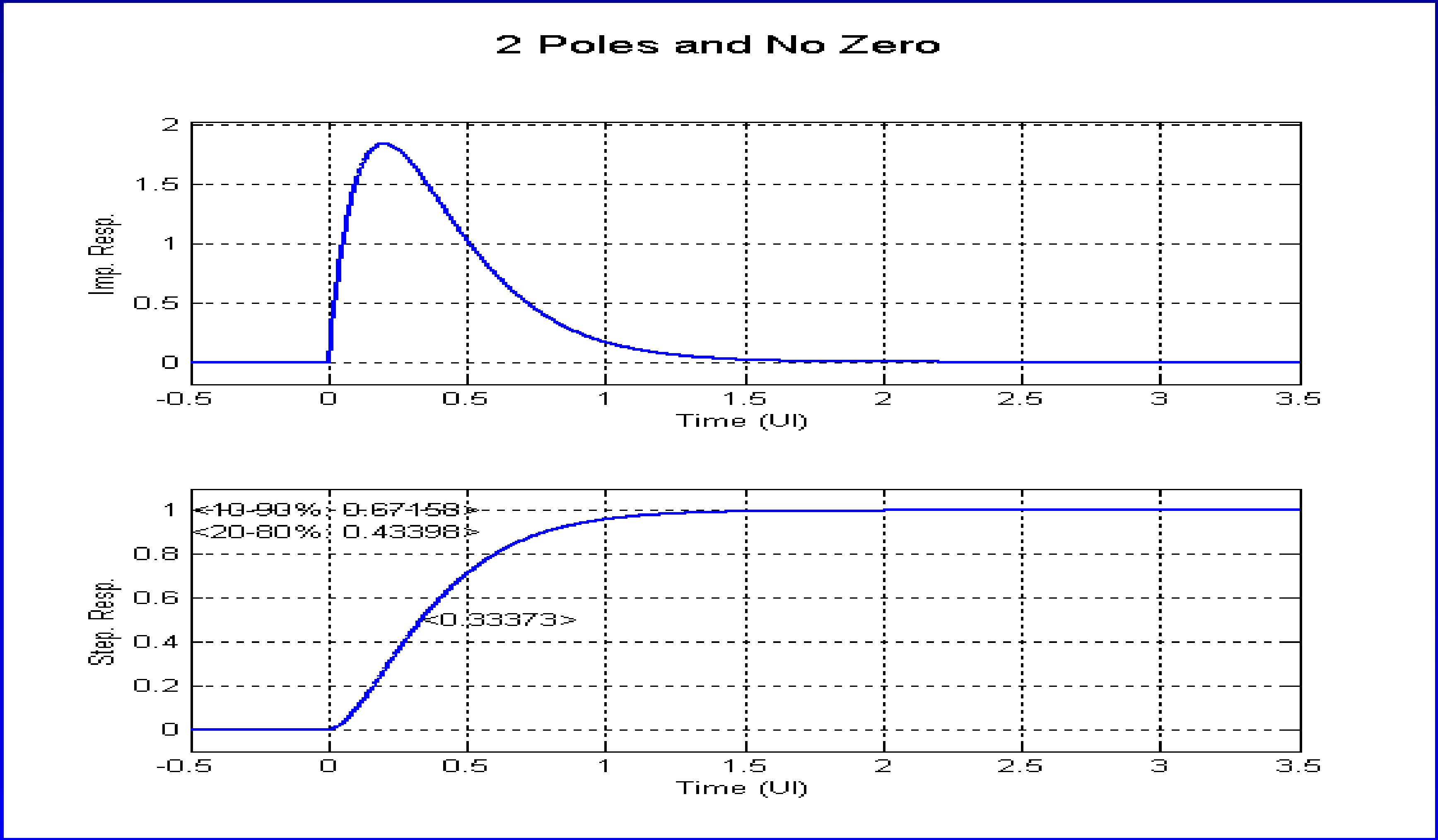
Case Study II: 2-Pole, 0-Zero

(a) Under Damped



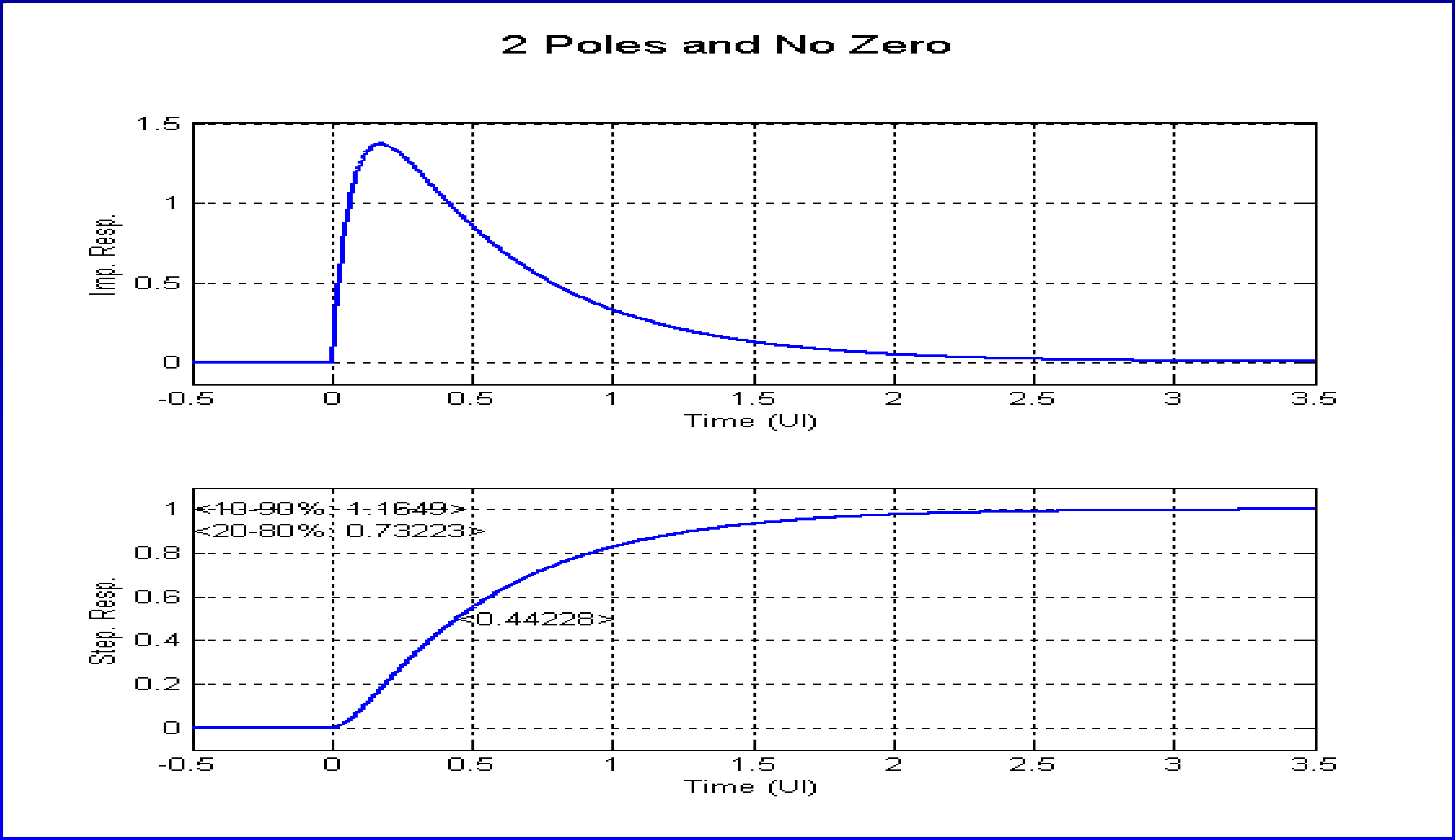
Case Study II: 2-Pole, 0-Zero Cont..

(b) Critically Damped

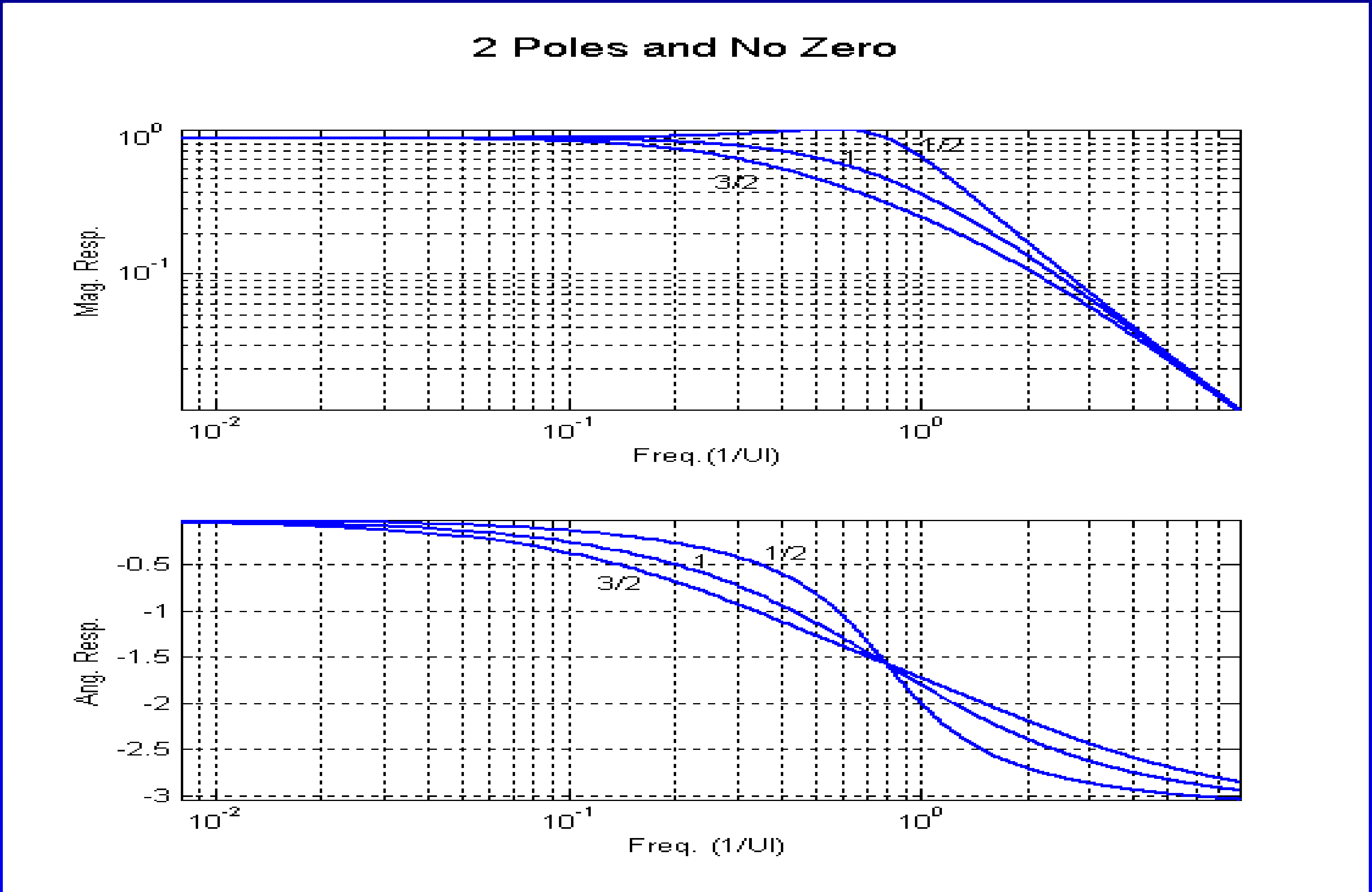


Case Study II: 2-Pole, 0-Zero Cont..

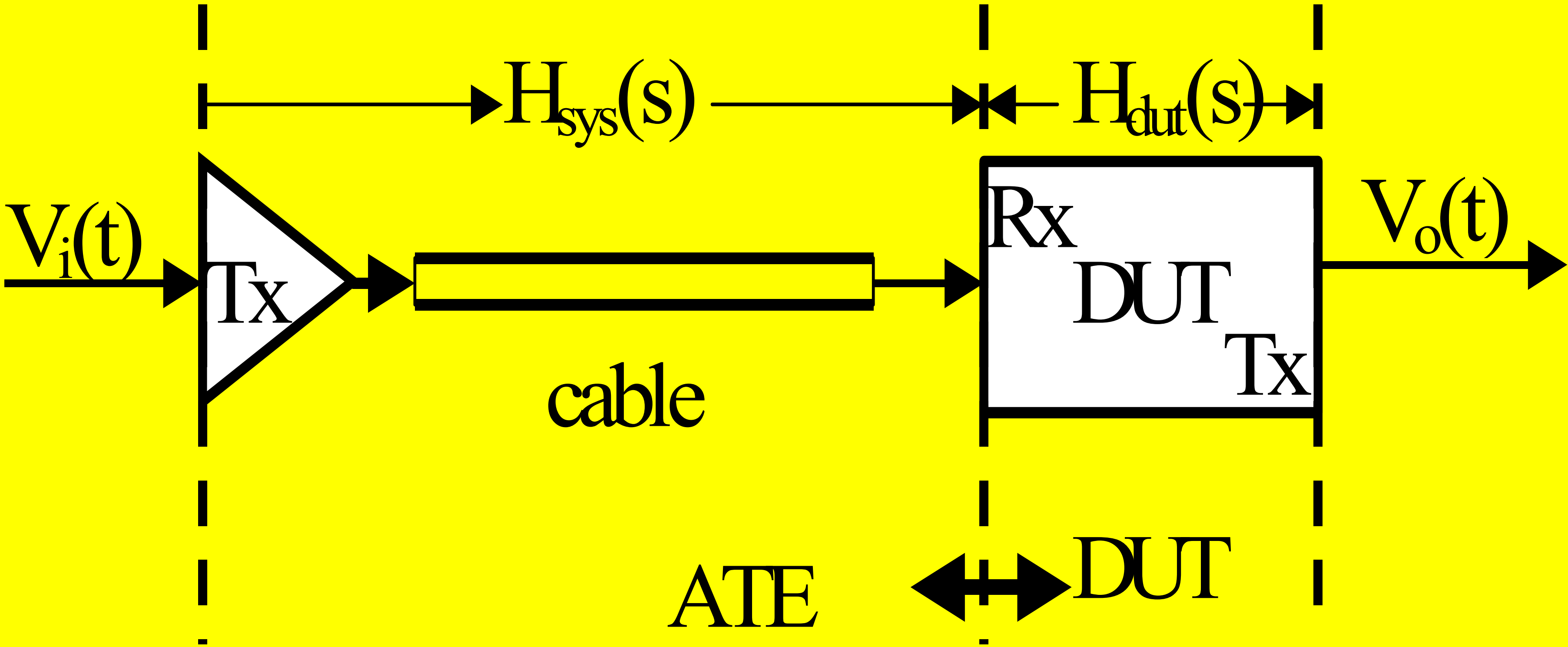
(c) Over Damped



Case Study II: 2-Pole, 0-Zero Cont..



Application to ATE DUT Path



Modeling Setup

$$H_t(s) = H_{sys}(s) \bullet H_{dut}(s)$$

$$h_t(t) = L^{-1}(H_t(s)) = \frac{1}{2\pi j} \int_{\sigma - j\omega}^{\sigma + j\omega} H_t(s) e^{st} ds$$

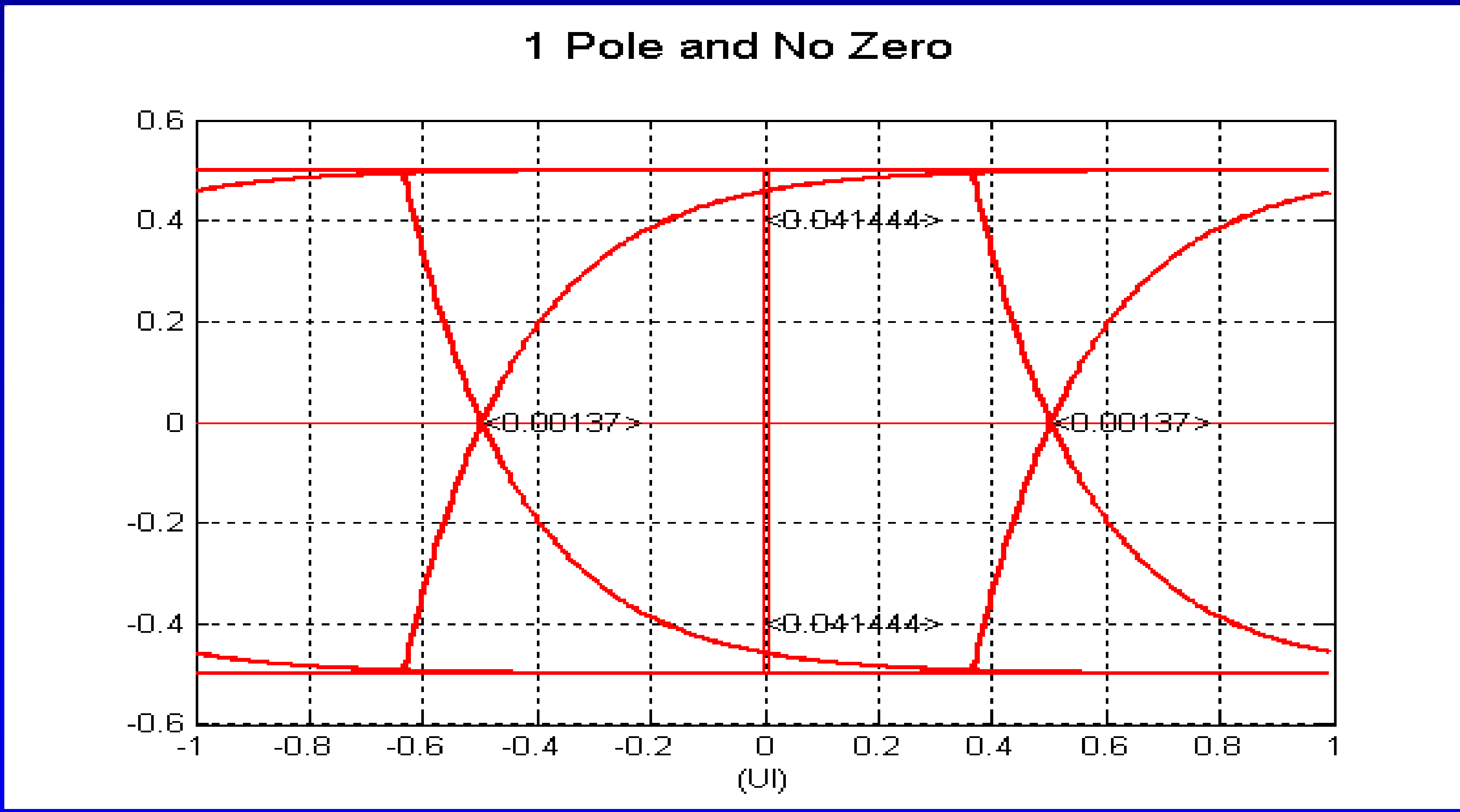
$$V_0(t) = h_t(t) * V_i(t)$$

Condition Settings

- $H_{dut}(s)$: assumed to be a 1st-order (1-pole), this is the baseline
- $H_{sys}(s)$: can be a 1st-order or a 2nd-order (1-pole, or 2-pole)
- $H_t(s)$: will be a 2nd-order or a 3rd-order (2-pole or 3-pole)
- $V_i(t)$: Datacom (K28.5, PRBS, CJTPAT) testing patterns

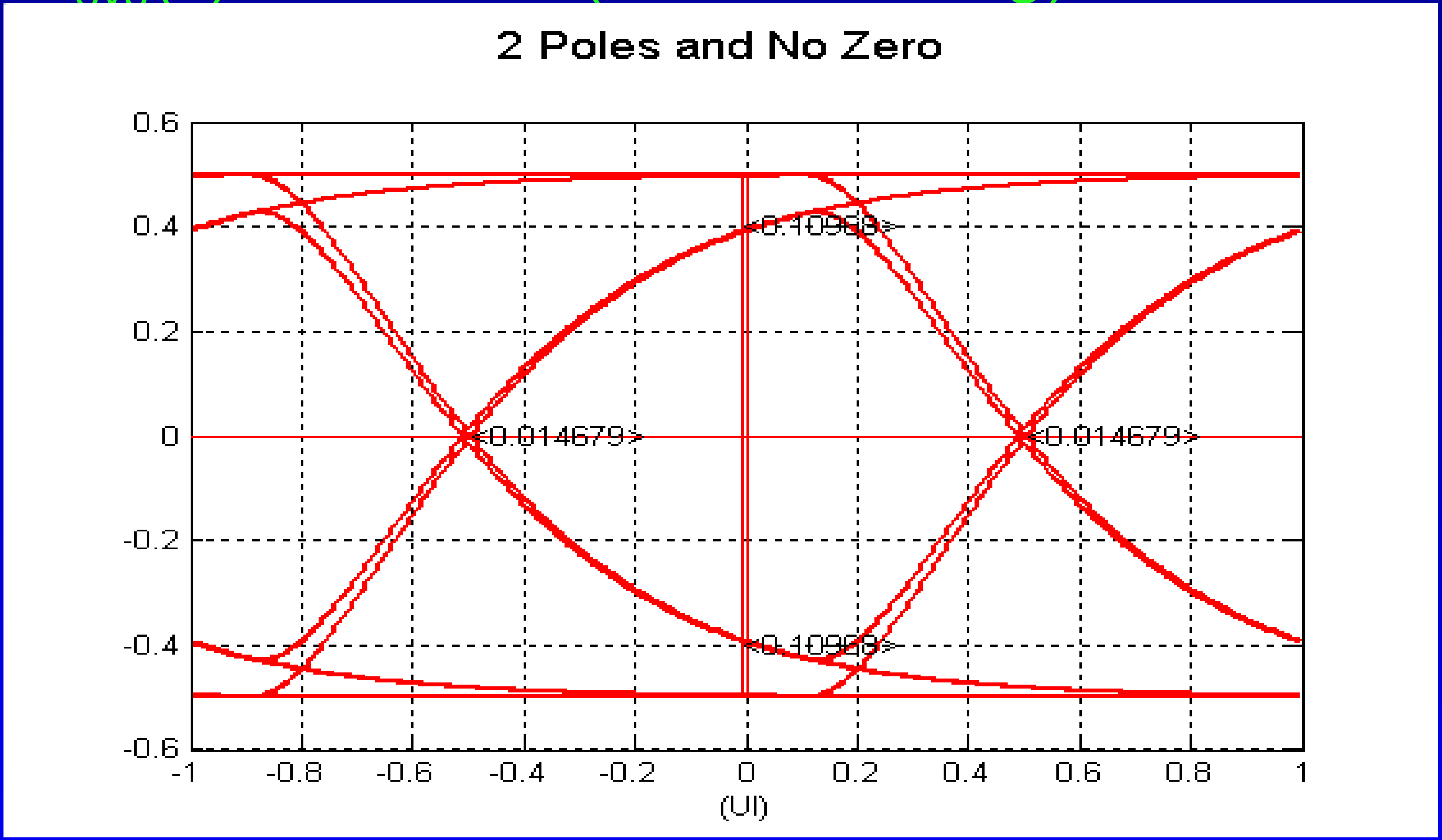
DUT Baseline Eye-Diagram

- $V_i(t)$: K28.5, $H_{dut}(s)$: 1st-order (~ 1 UI Settling)



Effects of “Bandwidth”

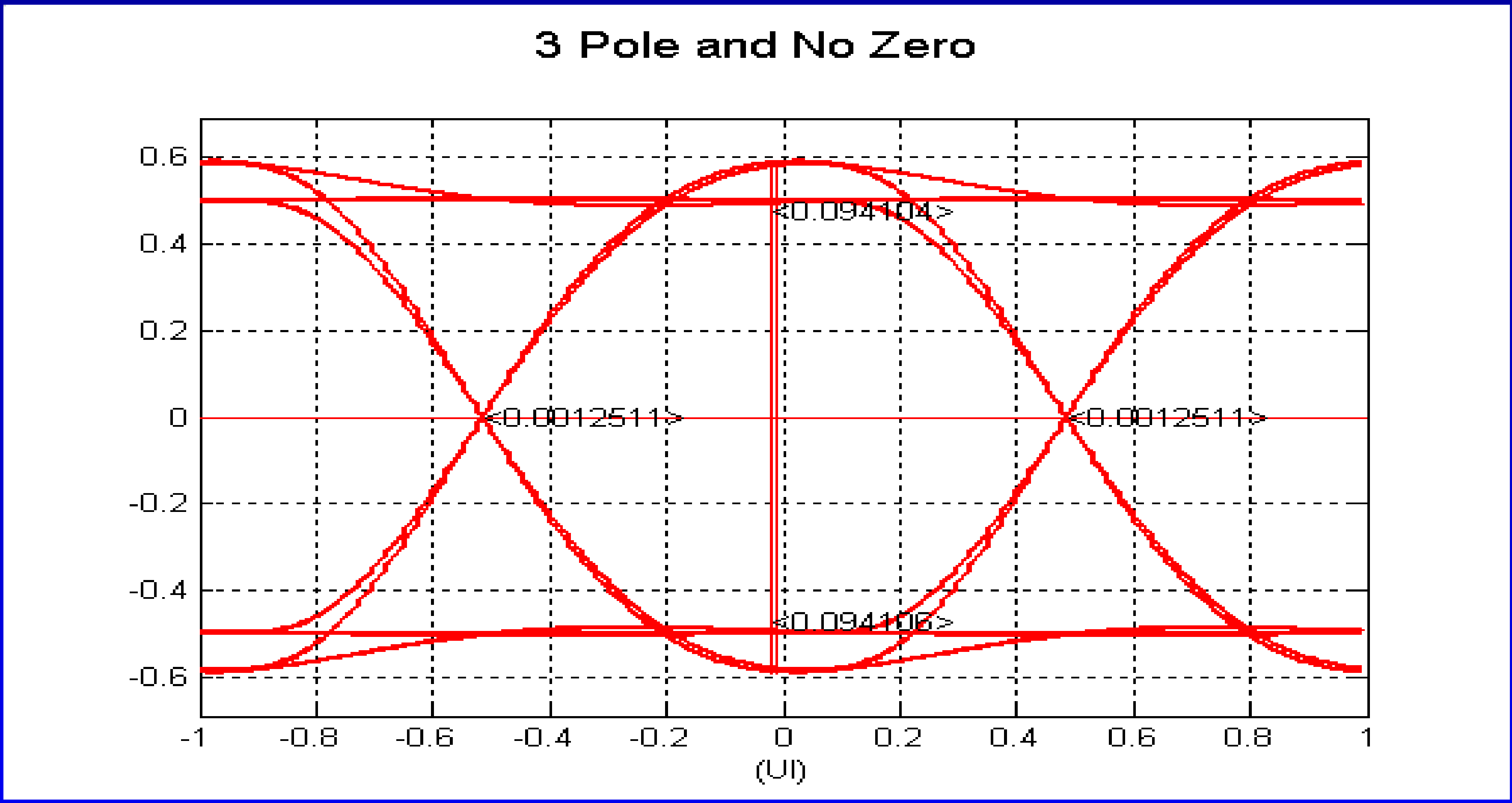
- $V_i(t)$: K28.5, $H_{dut}(s)$: 1st –order (~1 UI settling), $H_{sys}(s)$:1st –order (~2 UI settling)



$V_o(t)$ eye-diagram

Effects of Ringing

- $V_i(t)$: K28.5, $H_{dut}(s)$: 1st –order (~1 UI settling), $H_{sys}(s)$: 2nd –order (~2 UI settling)



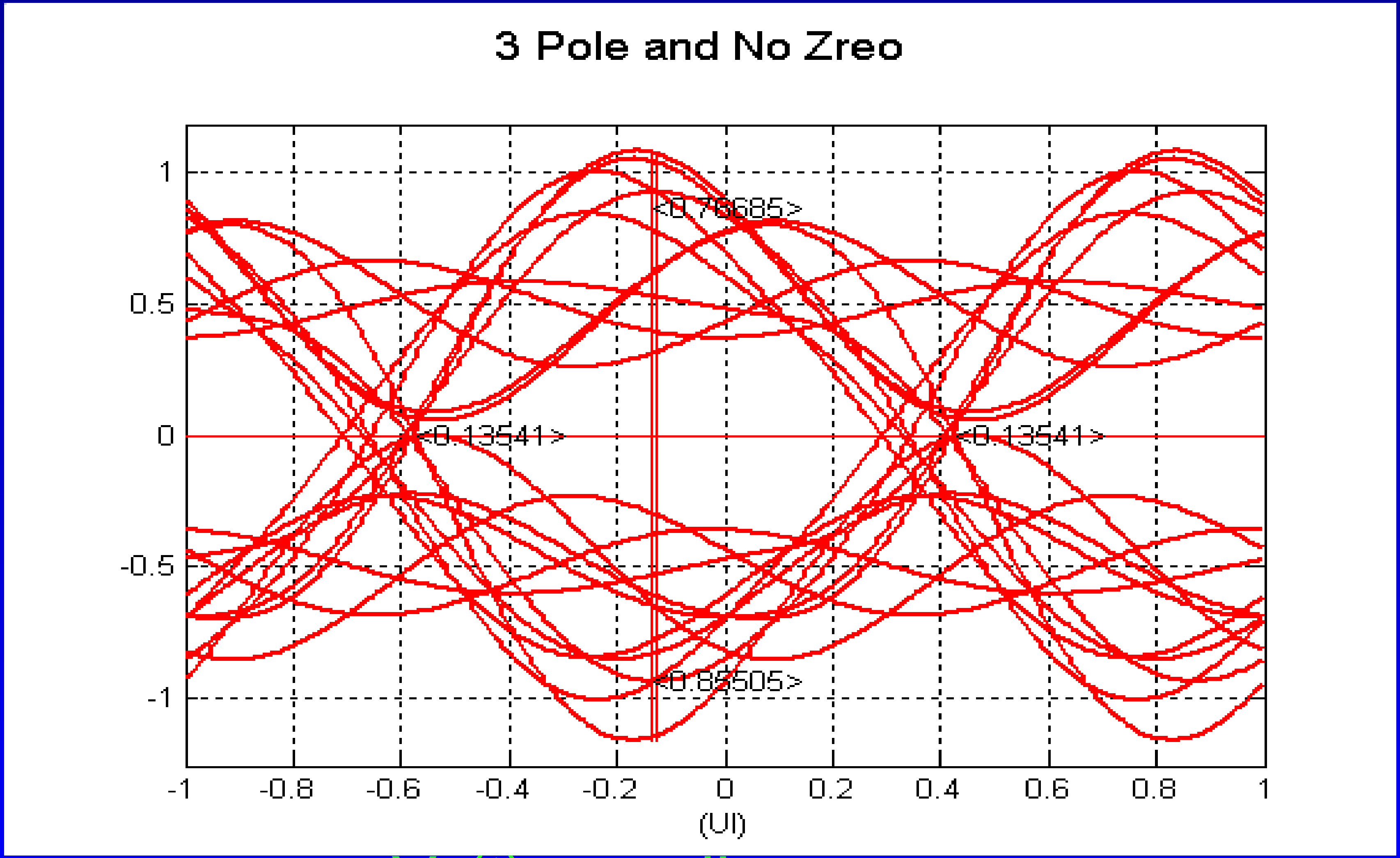
V (t) eye diagram

Summary Table for "Bandwidth" and Ringing Effects

	DUT	Effect of ATE "Bandwidth"		Effect of ATE Ringing	
		Total	ATE Induced	Total	ATE Induced
Timing ISI (UI)	0.0014	0.015	0.014	0.0013	-0.001
Voltage ISI (UA)	0.041	0.11	0.11	0.095	0.07

Effects of Data Pattern: K28.5

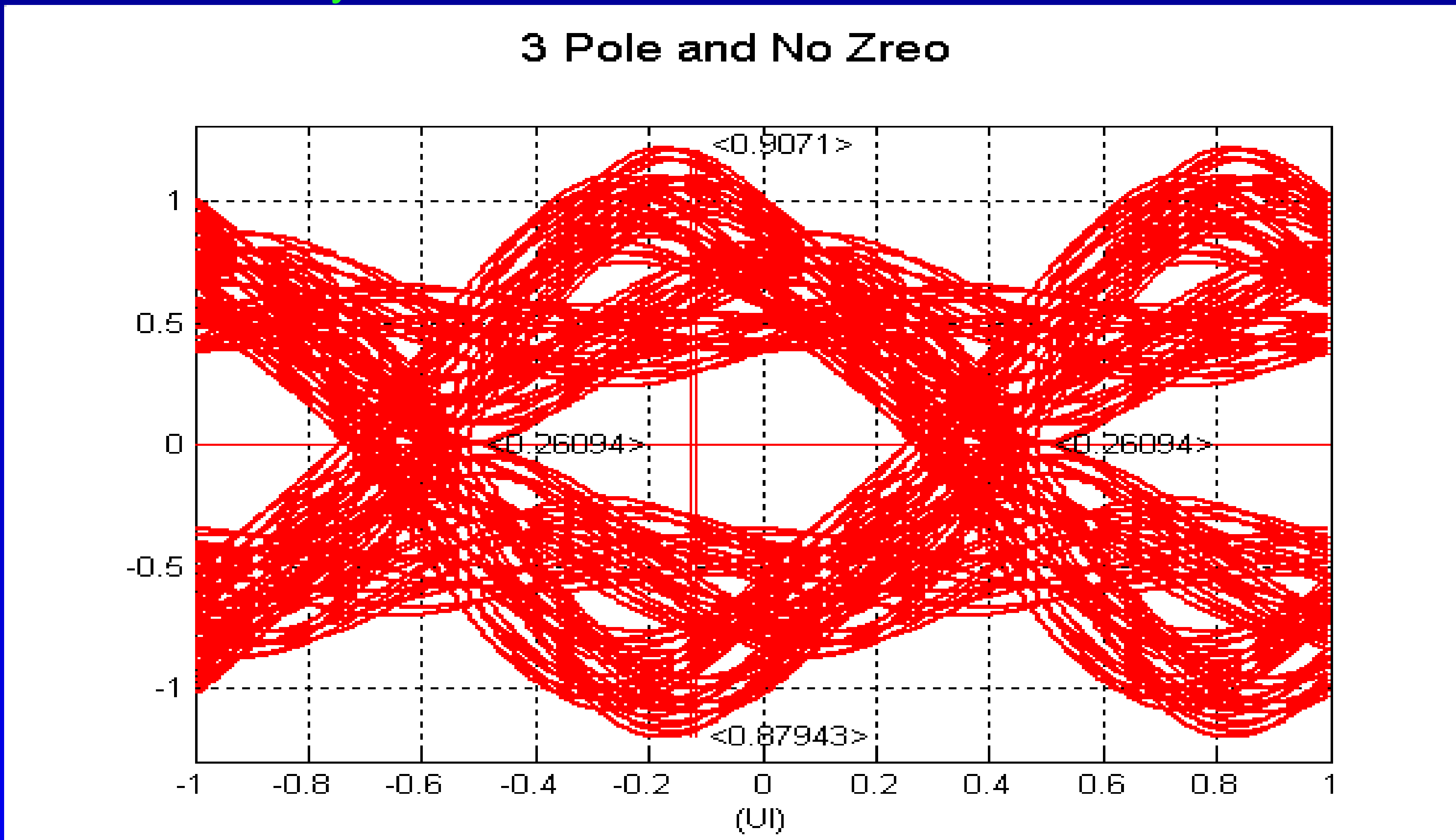
- $V_i(t)$: K28.5, $H_{dut}(s)$: 1st – order (~ 1 UI settling), $H_{sys}(s)$: 2nd –order (~ 8 UI settling)



V (t) eye diagram

Effects of Data Pattern: PRBS2^{10}-1

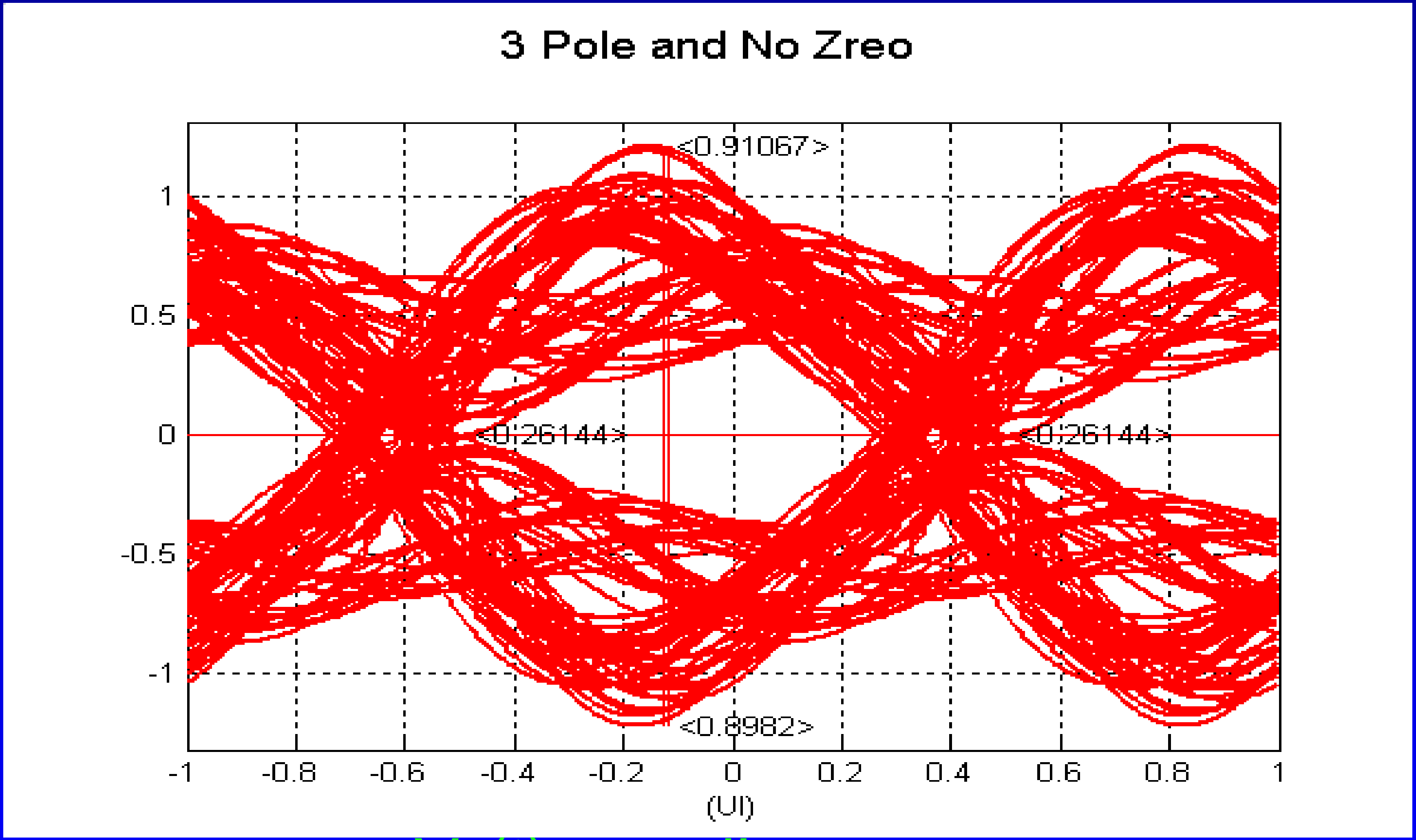
- $V_i(t)$: PRBS2^{10}-1, $H_{dut}(s)$: 1st – order (~ 1 UI settling), $H_{sys}(s)$: 2nd –order (~8 UI settling)



$V_o(t)$ eye-diagram

Effects of Data Pattern: CJTPAT

- Vi(t): PRBS2^{10}-1, $H_{dut}(s)$:1^{st} – order (~1 UI settling), $H_{sys}(s)$: 2^{nd} –order (~8 UI settling)



V (t) eye diagram

ummary Table for Different Pattern Effec

	K28.5	PRBS 2^{10}-1	CJTPAT
Timing ISI (UI)	**0.14**	**0.26**	**0.26**
Voltage ISI (UA)	**0.86**	**0.91**	**0.91**

Summary and Conclusion

- A generic Nth-order (or N-pole, M-zero) model is established
- The generic model ***eliminates*** all the limitations of th simple, commonly used 1st – order (1-pole) model (see references in the paper)
- ***Scalability and completeness*** aspects of the generic model are demonstrated
- Application of the generic model in Datacom ATE I/O path is illustrated
- Simple 1st – order model ***does not*** offer completeness and accuracy for high-speed Datacom ATE, and the generic model ***does***