Table-Based Extraction for Modeling Driver's Output Admittance

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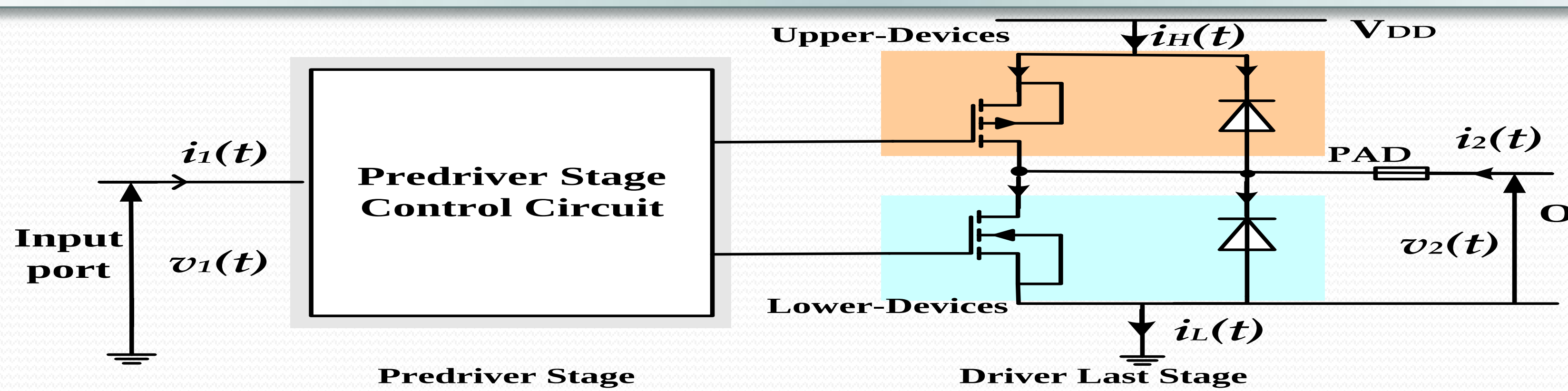
Presentation Outline

1. I/O Buffer Model Structure
2. Nonlinear Dynamic Behaviors Driver's Last Stage
3. Output admittance I-Q Model
4. Model Extraction Procedure
5. Step Input Describing Functions
6. Example of Extraction Results
7. Conclusions

I/O BUFFER MODEL STRUCTURE

The two port input/output buffer general structure with its relevant electrical variables.



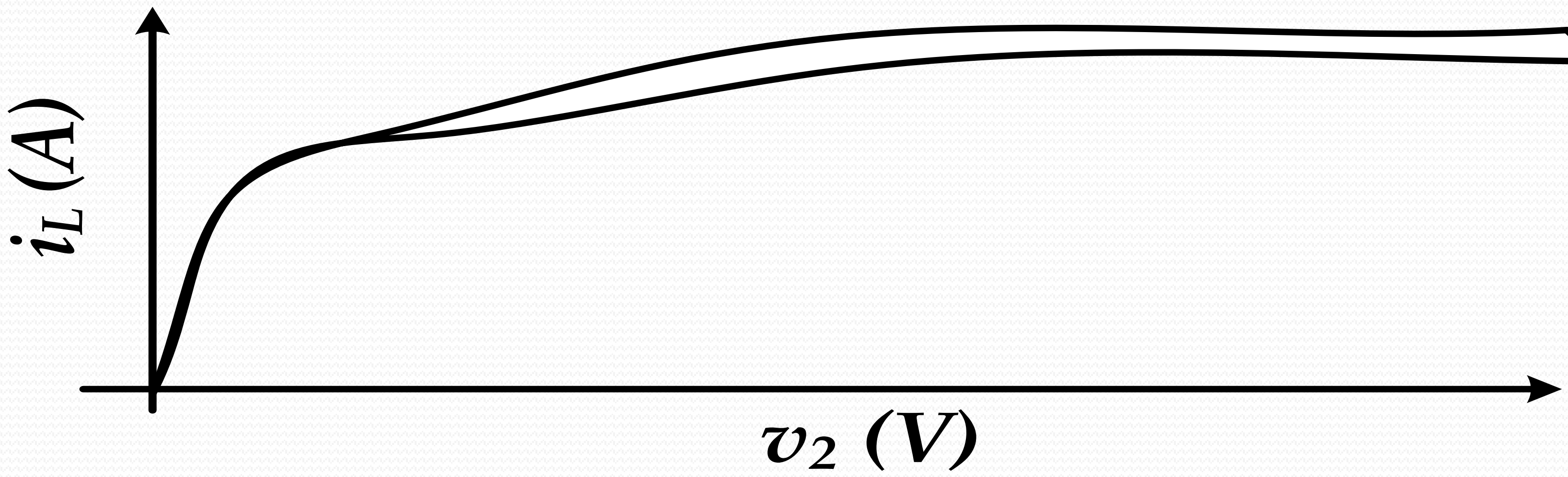
Global Model Structure :

$$i_2(t) = w_L(t).\, i_L(v_2(t), d/dt) + w_H(t).\, i_H(v_2(t), d/dt)$$

- $i_H(.)$ and $i_L(.)$ are local nonlinear dynamic functions describing the driver's last stage output impedance.
- w_H and w_L are step input describing functions (StDFs) capturing the behavior of the predriver device stage.

Objective: Develop a effective large-signal behavioral model Extraction valid for transient simulation.

LAST'S STAGE DRIVER BEHAVIOR

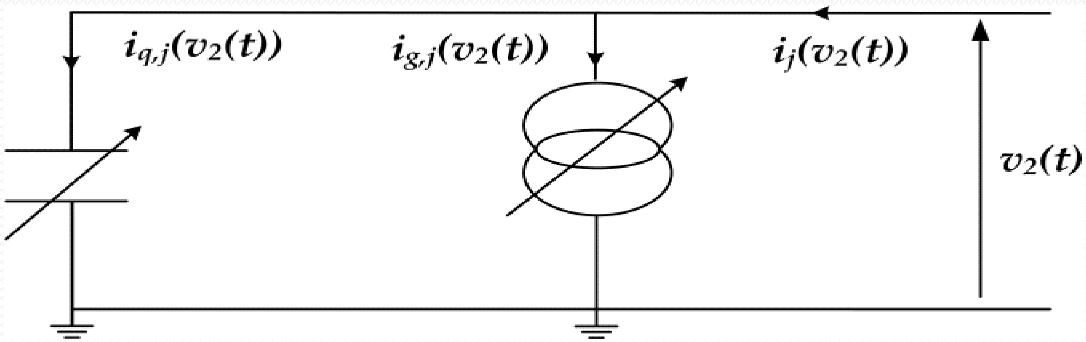


Nonlinear dynamic characteristic of the output port for the lower device under pulse excitation.

❖ **The looping in the trajectory in the I-V plane is a clear indication that the voltage-dependent capacitive effect is significant in the behavior of the one-port upper and lower devices of the driver's last stage.**

Output impedance I-Q Model

At a constant input voltage v_1, the output buffer can be considered as a one-port voltage-controlled device



One-port quasi-static representation of the upper or lower devices of the driver's last stage.

The description of this element in continuous-time domain is :

$$i_j(t) = G_j\big(v_2(t)\big) + \frac{dQ_j\big(v_2(t)\big)}{dt}; \;\; j = L, H.$$

$$C_j\big(v_2(t)\big) = \frac{dQ_j\big(v_2(t)\big)}{dv_2(t)} \Rightarrow i_j(t) = G_j\big(v_2(t)\big) + C_j\big(v_2(t)\big)\frac{dv_2(t)}{dt}$$

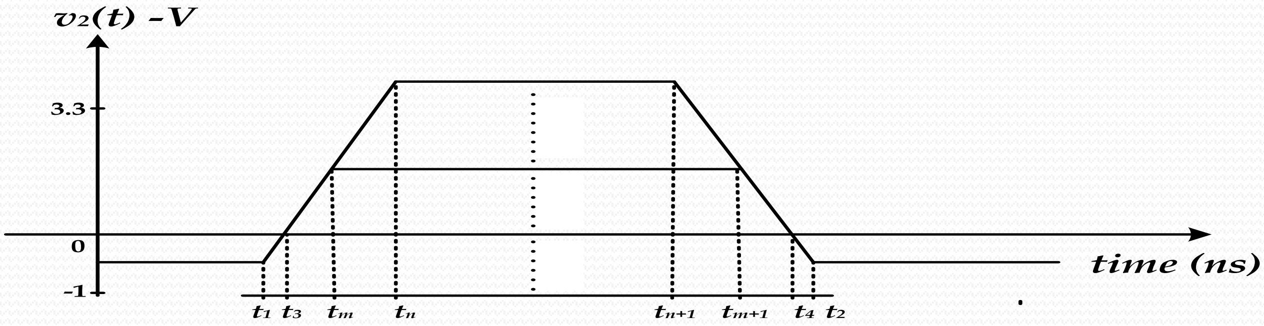
Model Extraction Procedure

❖**The new extraction procedure relies on the linear least-squares method.**

❖ It is possible to extract the $C_j(.)$ and $G_j(.)$ **by only one transient measurement.**

❖**Firstly,** the excitation voltage v_2 is a pulse with short t_r/t_f that covers all the voltage amplitude range. Then, we record the transient response v_2(t), i_{2j}(t).

❖**Secondly,** pick the duplicate values of the voltage amplitudes at different time instants t_1 and t_2 that verify $v_2(t_1)$ and $v_2(t_2)$ their corresponding currents $i_j(t_1)$ and $i_j(t_2)$.



❖**Thirdly,** since the state functions are single-valued, so that they depend only on the instantaneous excitation voltage, $C_j(t_1) = C_j(t_2)$ and $G_j(t_1) = G_j(t_2)$.

Model Function's Extraction

The value of the output voltage derivative at the time instant t_k

$$E(t_k) = \left.\frac{dv_2(t)}{dt}\right|_{v_2(t)=v_2(t_k)}$$

We can write the I-Q model for the time instants t_1 and t_2

$$\begin{cases} i_j(t_1) = G_j\left(v_2(t_1)\right) + C_j\left(v_2(t_1)\right).E(t_1) \\ i_j(t_2) = G_j\left(v_2(t_2)\right) + C_j\left(v_2(t_2)\right).E(t_2). \end{cases}$$

The C_j *(.)* and G_j*(.)* functions are obtained by a linear inversion

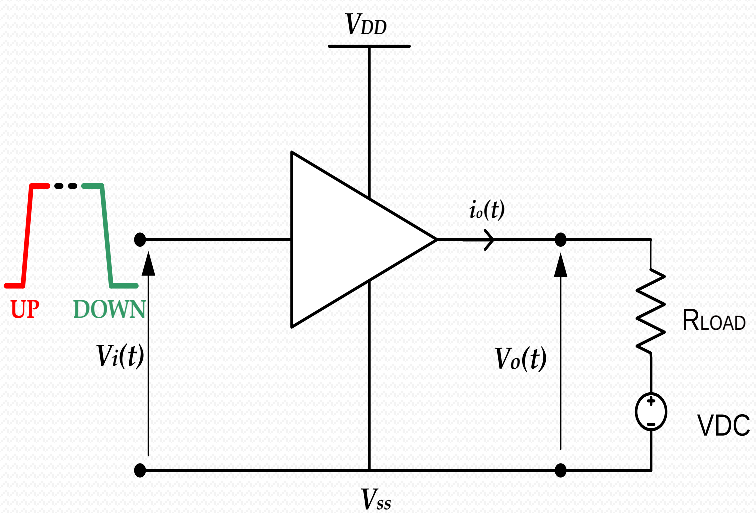
$$\begin{bmatrix} G_j\left(v_2(t_1)\right) = G_j\left(v_2(t_2)\right) \\ C_j\left(v_2(t_1)\right) = C_j\left(v_2(t_2)\right) \end{bmatrix} = \begin{bmatrix} 1 & E(t_1) \\ 1 & E(t_2) \end{bmatrix}^{-1} . \begin{bmatrix} i_L(t_1) \\ i_L(t_2) \end{bmatrix}$$

W. Dghais, H. M. Teixeira, T. R. Cunha, and J. C. Pedro "Novel Extraction of Table-Based I-Q Behavioral Model for High-Speed Digital Buffers/Drivers", IEEE Trans. on Components, Packaging and Manufacturing Technology March 2013.

StDFs Extraction

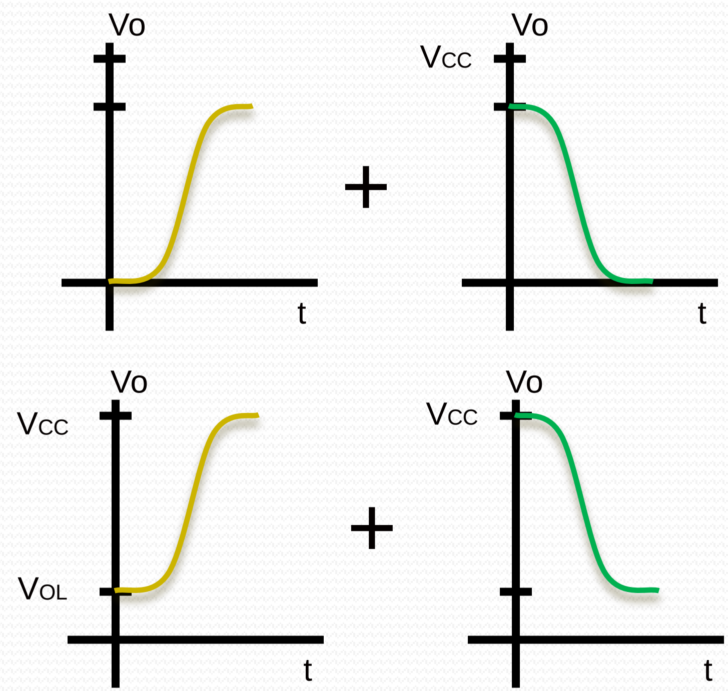
The $w_L(.)$ and $w_H(.)$ give the transient information about the predriver's nonlinear dynamics

The transient identification signal data



•**VDC = GND**

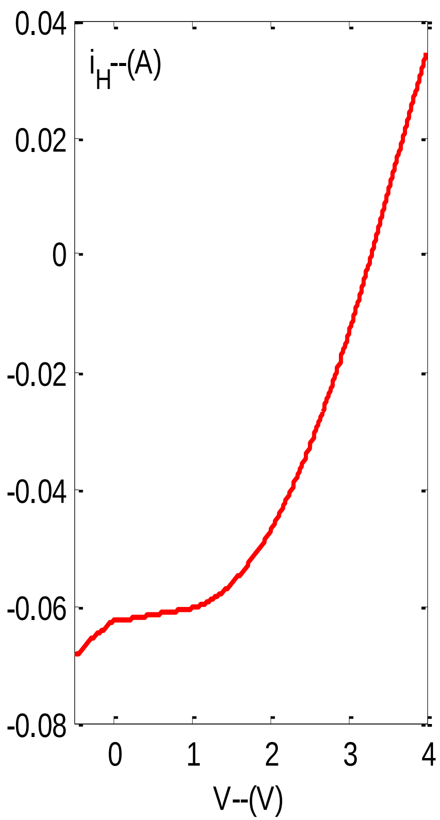
•**VDC = VDD**

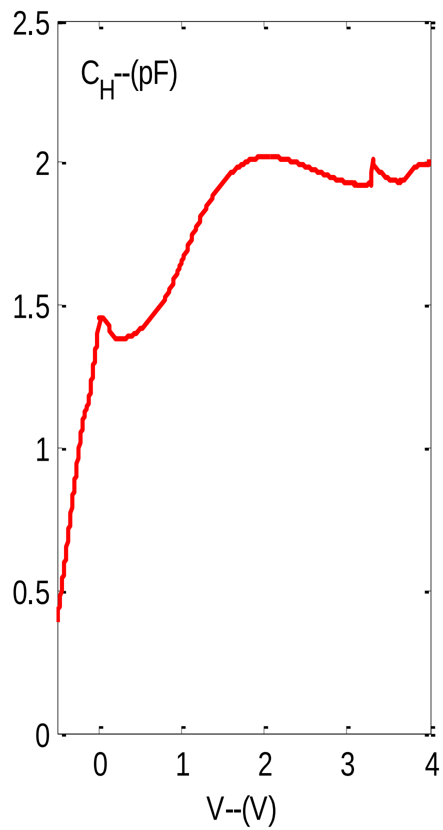


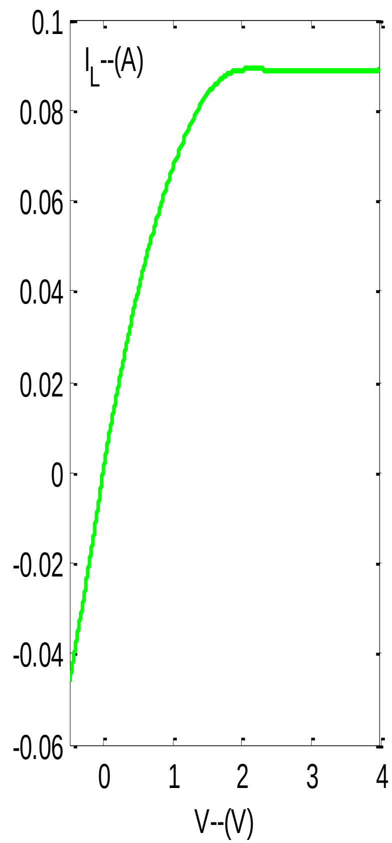
$$\begin{bmatrix} w_L(t) \\ w_H(t) \end{bmatrix} = \begin{bmatrix} i_{L,gnd}(t) & i_{H,gnd}(t) \\ i_{L,Vdd}(t) & i_{H,Vdd}(t) \end{bmatrix}^{-1} \begin{bmatrix} i_{2,gnd}(t) \\ i_{2,Vdd}(t) \end{bmatrix}$$

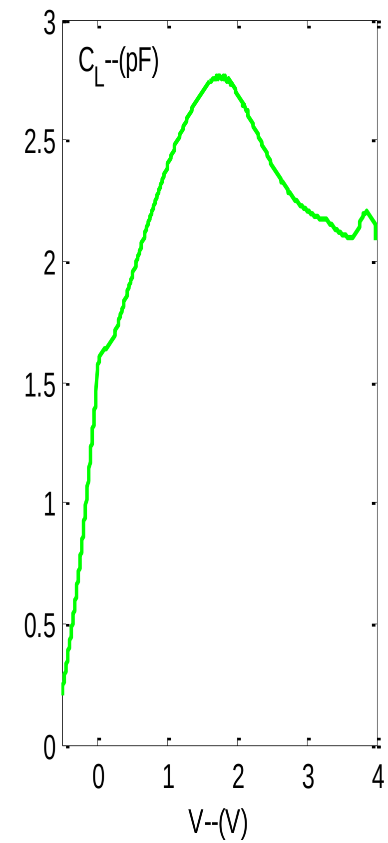
EXAMPLE OF EXTRACTION RESULT

Conduction and displacement single valued nonlinearities for the upper, and the lower devices of the driver's last stage.

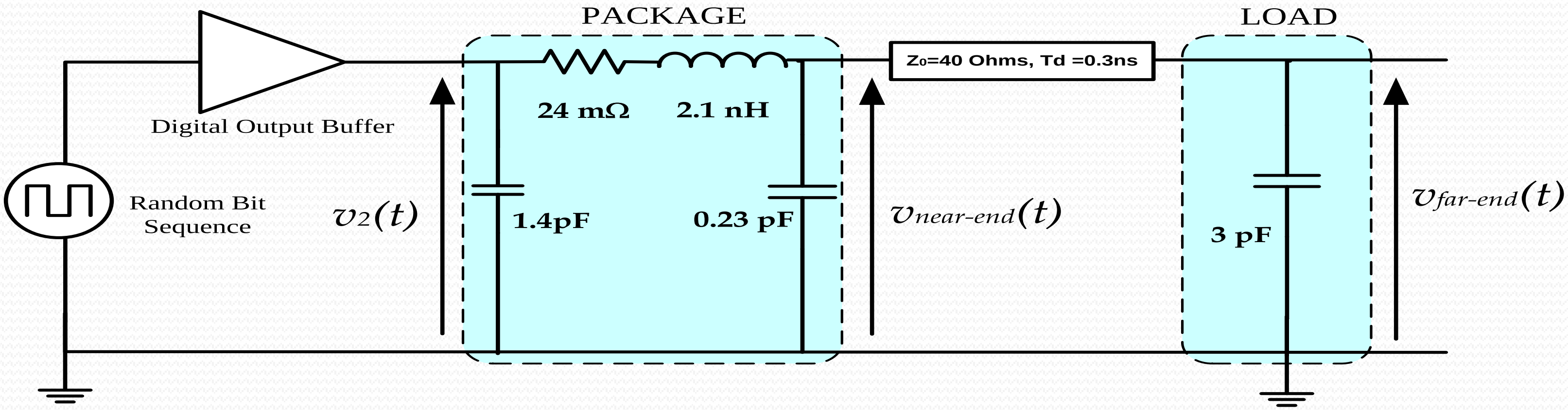


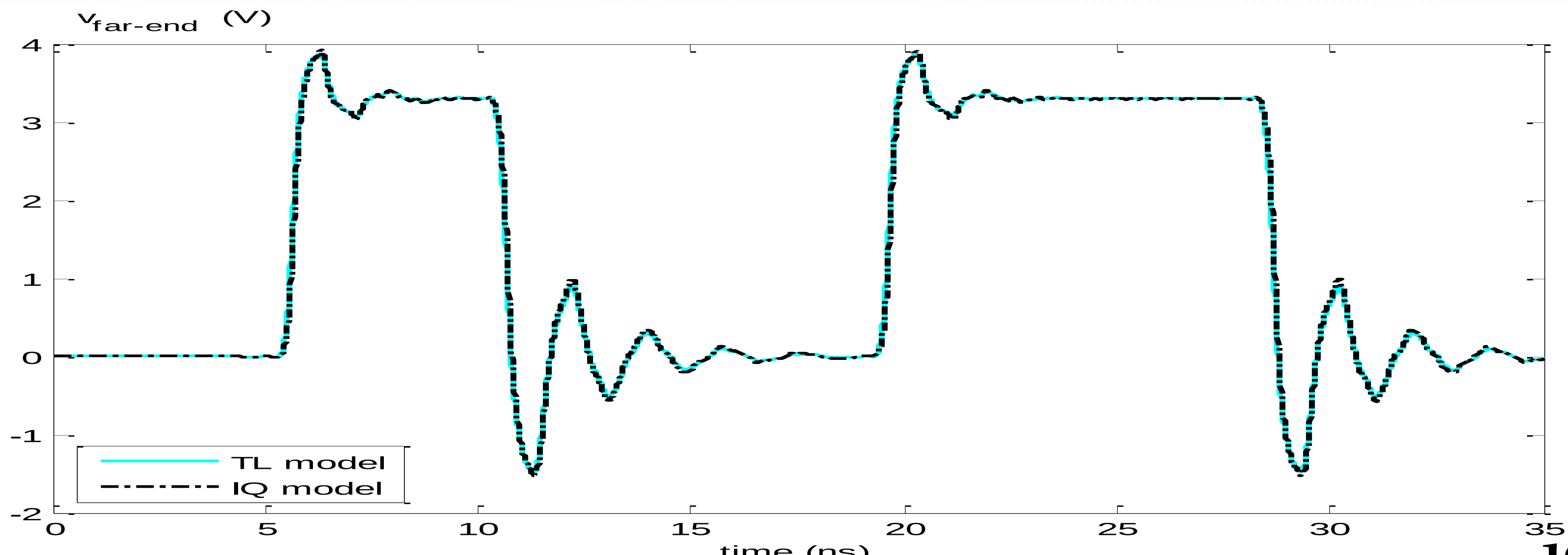






VALIDATION RESULTS





CONCLUSIONS

❖**A new extraction** procedure of the I-Q behavioral model is based on the linear least-squares optimization method, **which avoids the drawbacks of nonlinear optimization algorithms** (such as instability, local minima, training time, and dependence on parameter initialization) used for the training of artificial neural networks-based models.

❖Additionally, **the fast extraction and easy implementation help the automation of the I-Q behavioral model generation.**

❖The extracted I-V and Q-V functions **physically describe** the the electrical output impedance of the driver's last stage.

❖**The proposed formulation is more accurate as the IBIS model, for the same level of computational complexity.**

Thank You for your Attention

Questions?