Parametric Models in IBIS Multilingual Framework

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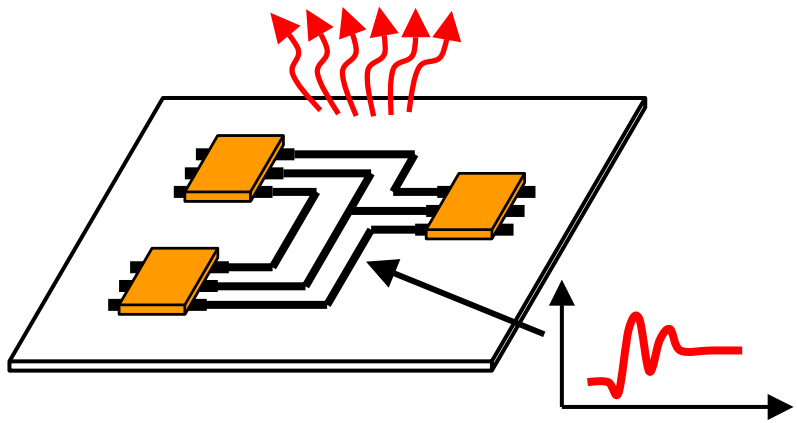
Introduction (i)

IBIS Implementation of I/O buffer Parametric Models for High-Performance SI and EMC simulations

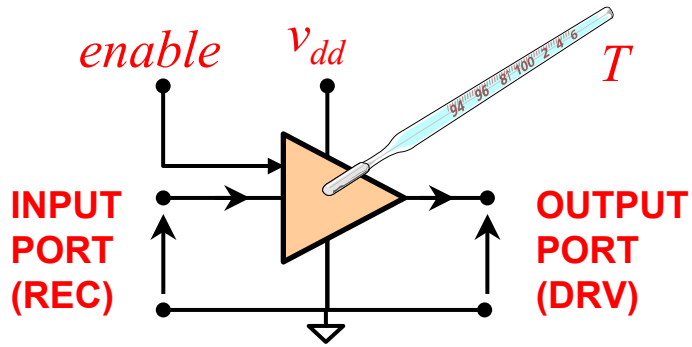


Improved modeling of latest technologies and high-order effects

- LVDS drivers with pre-emphasis,
- DDR memories,
- Power supply ports, etc …

Introduction (ii)

M*πlog* - **M**acromodeling via parametric identification (π) of **LO**gic **G**ates



Available applications:

Single-ended CMOS

- **Macromodels** of I/O ports
- Inclusion of slowly-varying **device parameters** (eg, temperature)
- Inclusion of the **power-supply voltage** variation
- Models of the **power supply port**
- Models of **tristate drivers**

[I.S.Stievano, I.A.Maio, F.G.Canavero, "M*πlog*, Macromodeling via Parametric Identification of Logic Gates," Trans. Of Adv. Pack., 2003 (in press)]

- Models of **LVDS** devices

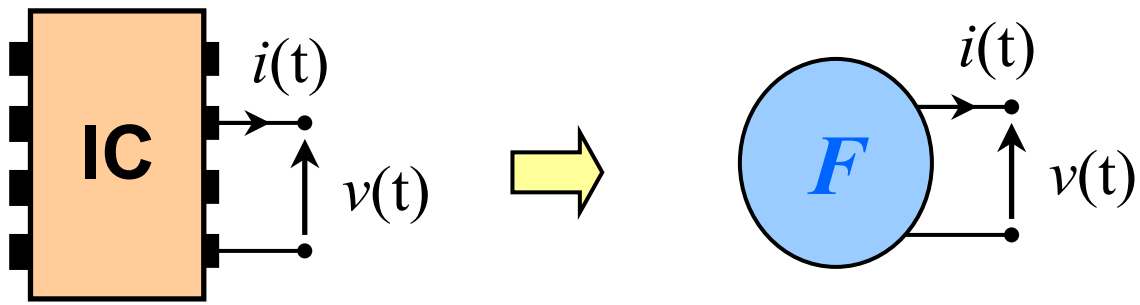
[I.S.Stievano, C.Siviero, I.A.Maio, F.G.Canavero, "Modeling of the Static and Dynamic Behavior of Differential Drivers," Proc. of EMC-Compo 2004]

Mπ*log* review (i)

Mπ*log* - **M**acromodeling via parametric identification (π) of **LO**gic **G**ates

What is it ?

A **mathematical expression** reproducing the electrical behavior of the device



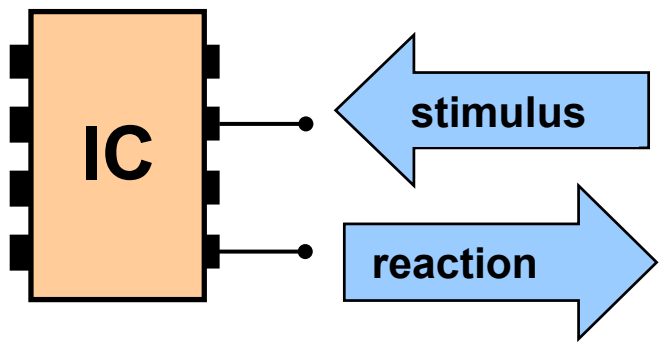
$$i = F(v,\ d/dt)$$

Nonlinear dynamic relationship

Mπlog review (ii)

How does it work ?

- Real Device (or its physical model) is conveniently **stimulated**
- **Reaction (port transient responses)** is used to build the model



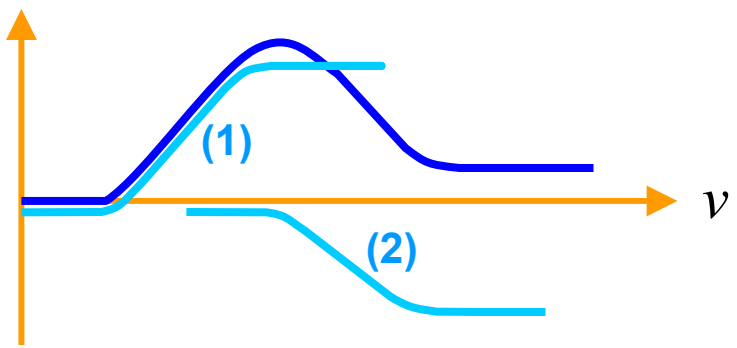
Mπlog: what is the output ?

Model structure: F is a Σ nonlinear **Basis Functions (various types)**

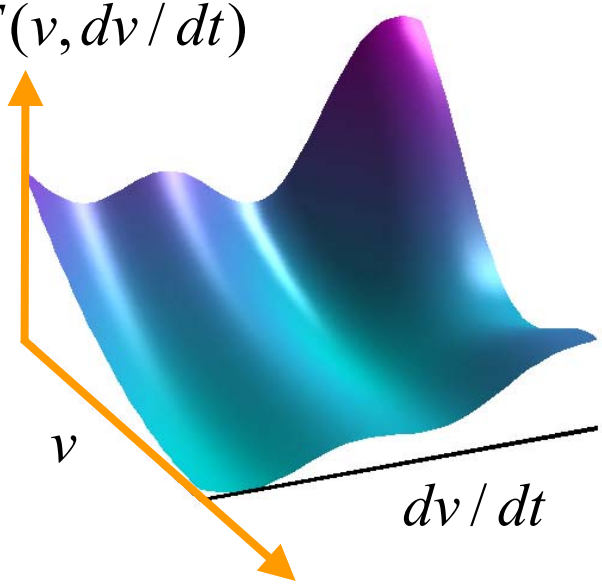
e.g., $$i = -a_1 \tanh\{c_1 v + b_1\} + a_2 \tanh\{c_2 dv/dt + b_2\}$$

(1) (2)

$i = F(v, dv/dt)$



$i = F(v, dv/dt)$

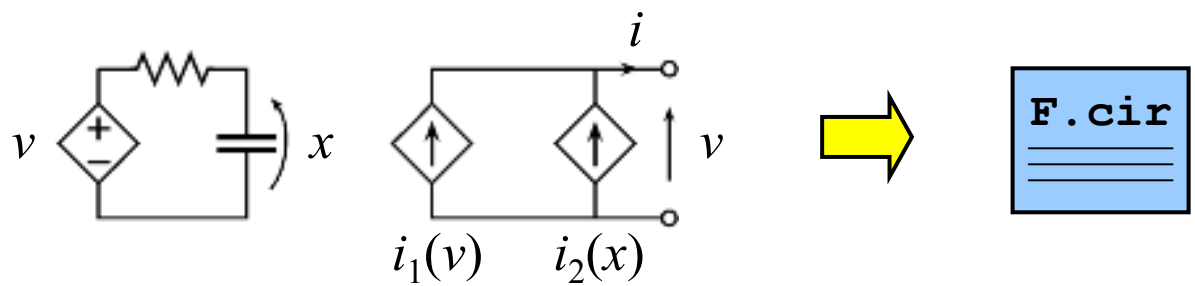


unknown parameters: **amplitude, position, spreading**

Mπ*log*: implementation

$$i = \underbrace{-a_1 \tanh\{c_1 v + b_1\}}_{i_1} + \underbrace{a_2 \tanh\{c_2 \, dv/dt + b_2\}}_{i_2}$$

(a) CIRCUIT INTERPRETATION & SPICE IMPLEMENTATION



(b) DIRECT EQUATION DESCRIPTION/IMPLEMENTATION:

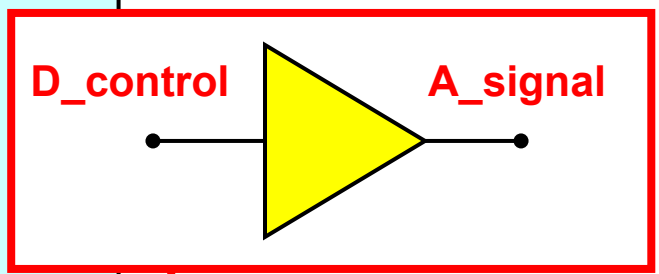
VHDL-AMS and IBIS Multilingual Extension

for Mentor Graphics **ICX Ver. 3.2 simulator**

IBIS Multilingual Extension

Driver_test.ibs

```
[IBIS Ver]      4.0
[File name]     driver_test.ibs
[File Rev]      0.0
[Date]          28/01/2004
|*****************************************************************************
[Component]     DRIVER
[Manufacturer]  Polito
[Package]  …
…
[Pin]  signal_name   model_name    R_pin    L_pin      C_pin
1      vout          MODEL_PAR
|*****************************************************************************
|
[Model]  MODEL_PAR
Model_type      Output
Polarity        Non-Inverting
…
[External Model]
Language  VHDL-AMS
|
| corner_name     file_name        circuit_name
Corner  Typ       driverX.vhd      driverX(bufferbehav)
|
|       d_control  a_signal
Ports   D_control  A_signal
|
[End External Model]
```



NOTE: some example syntax details differ slightly from the approved IBIS Version 4.1 specification

VHDL-AMS Model Implementation (i)

driverX.vhd

```
entity driverX is
 generic (
   Ts: real := …
  port(
        d_control : in std_logic;
        terminal a_signal : electrical);
end entity driverX;

architecture bufferbehav of driverX is
  quantity Vu_ref across i through a_signal
  to Electrical_ref;
  …
  --- w1_01 low to high transition
  constant w1_01 : real_vector := …

  InputBITSTR: process (d_control)
    begin
     if (d_control'event and d_control = '0') then
                  flag <= 10;
                  trans_inst <= now;
     elsif (d_control'event and d_control = '1') then
                  flag <= 01;
                  trans_inst <= now;
     end if;
  end process InputBITSTR;
  …
```

1

Digital to analog conversion

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VHDL-AMS Model Implementation (ii)

Analog parametric model

driverX.vhd

```
…
…
…
if (d_control = '0' and flag = 10) use
    w1 == Lookup("Vt", now-trans_inst, w1_10, tw);
    w2 == Lookup("Vt", now-trans_inst, w2_01, tw);
  elsif (d_control = '1' and flag = 01) use
    w1 == Lookup("Vt", now-trans_inst, w1_01, tw);
    w2 == Lookup("Vt", now-trans_inst, w2_10, tw);
end use;

f1 == -a1*(2/(1+exp(-2*c1*Vu_ref +…) –1) + …
f2 == …
i ==  w1*f1 + w2*f2

end architecture bufferbehav;
```

2

Example representation for CMOS single ended drivers

$$i = w_1(t) f_1(v, dv/dt) + w_2(t) f_2(v, dv/dt)$$

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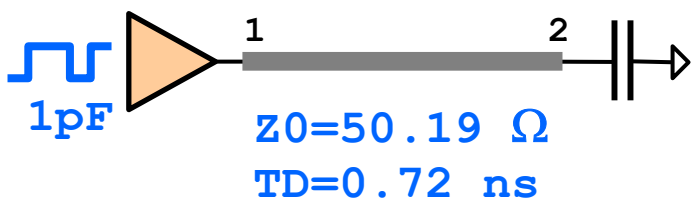
Example 1 (i)

DEVICE High-speed IBM CMOS Driver (V_{dd}=1.8V)

PARAMETRIC MODEL 1 (2) basis functions for f_1 (f_2) and and dynamic order 1

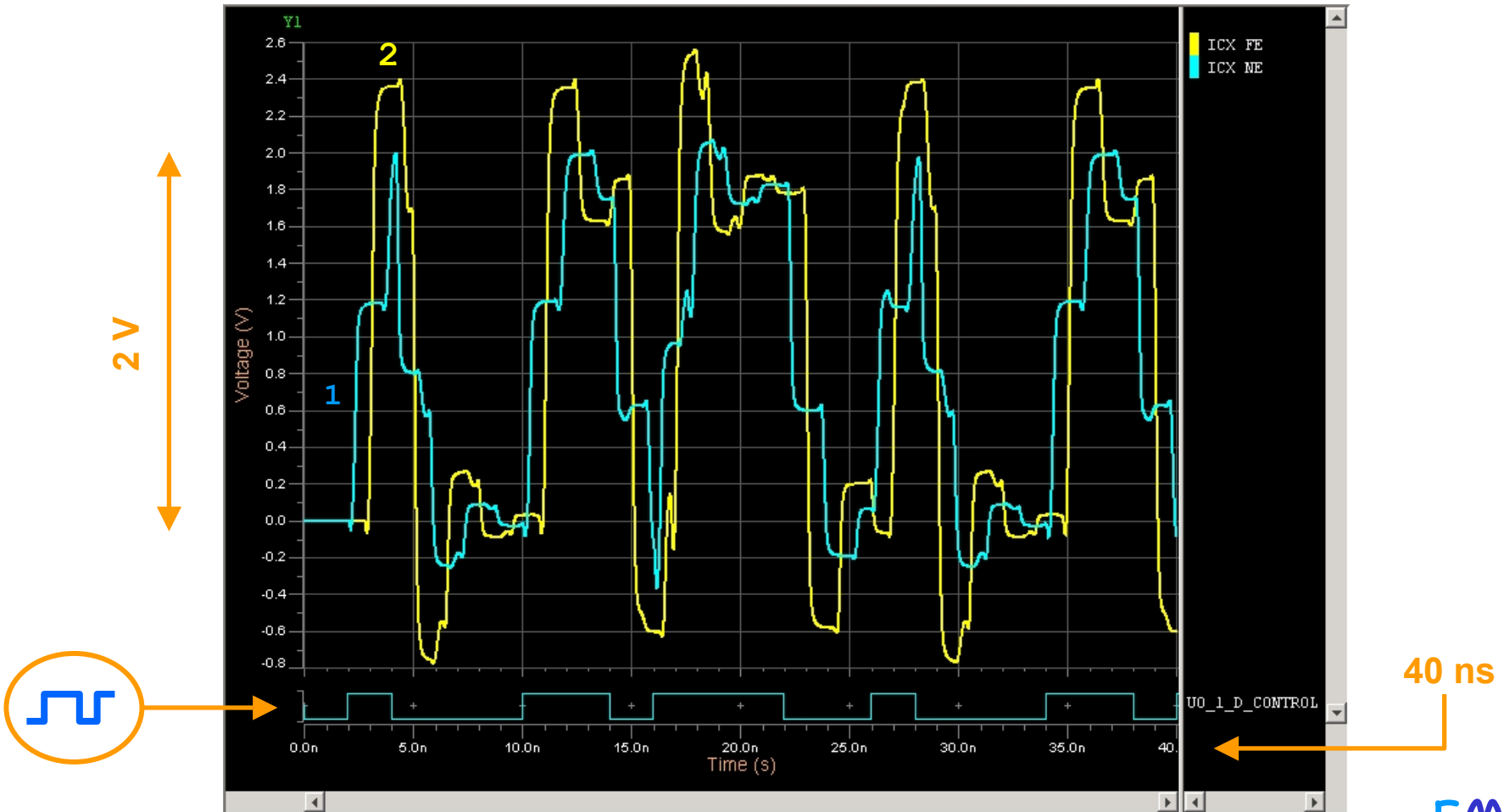
[I.S.Stievano et Al., "Parametric Macromodels of Drivers for SSN Simulations," Proc. of IEEE International Symposium on EMC, Boston, MA, USA, Aug. 18-22, 2003]

TEST CIRCUIT



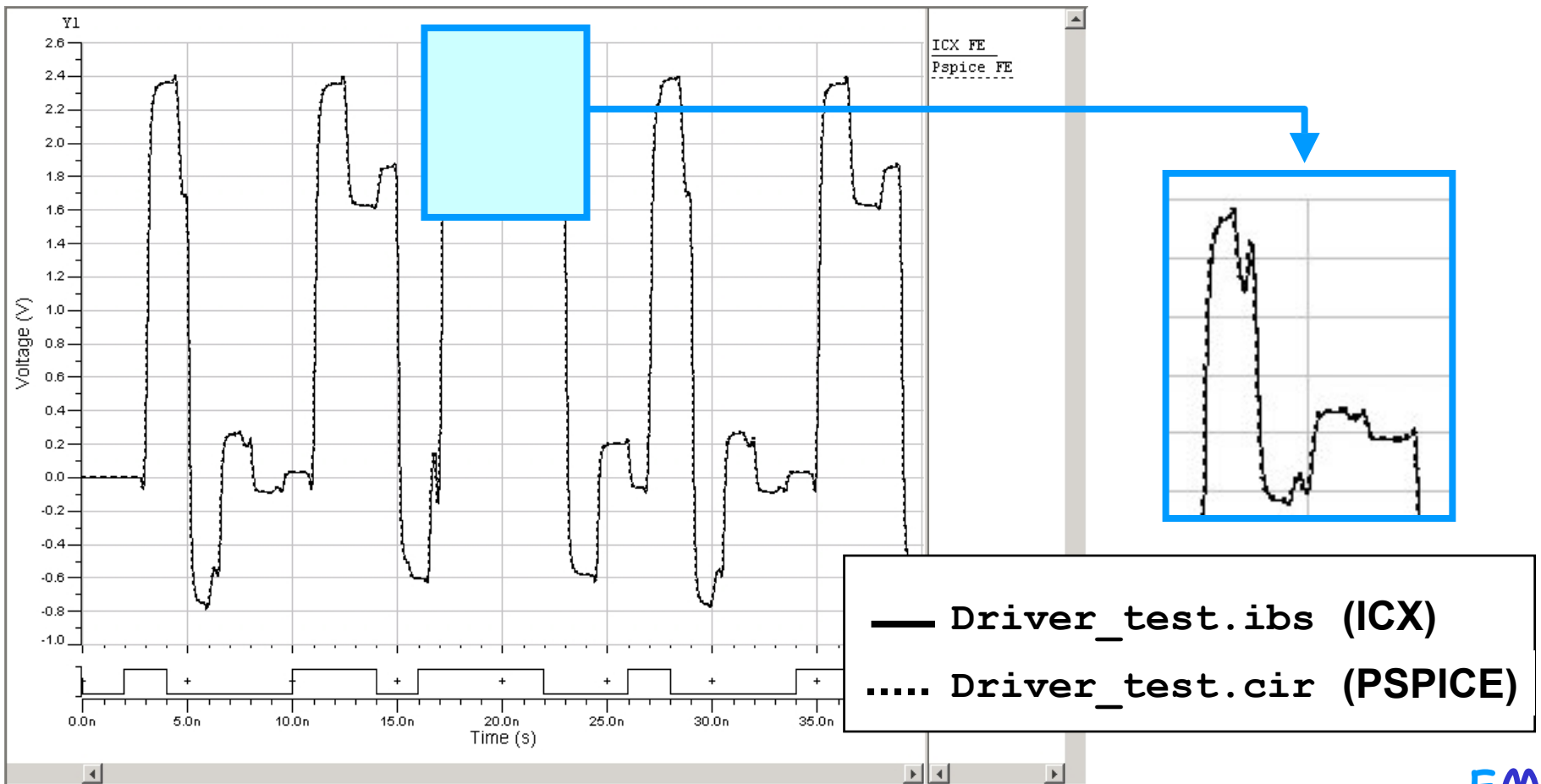
Example 1 (ii)

`Driver_test.ibs` **simulation: ICX**



Example 1 (iii)

Comparison of `Driver_test.ibs` & `Driver_test.cir`



Example 2 (i)

DEVICE

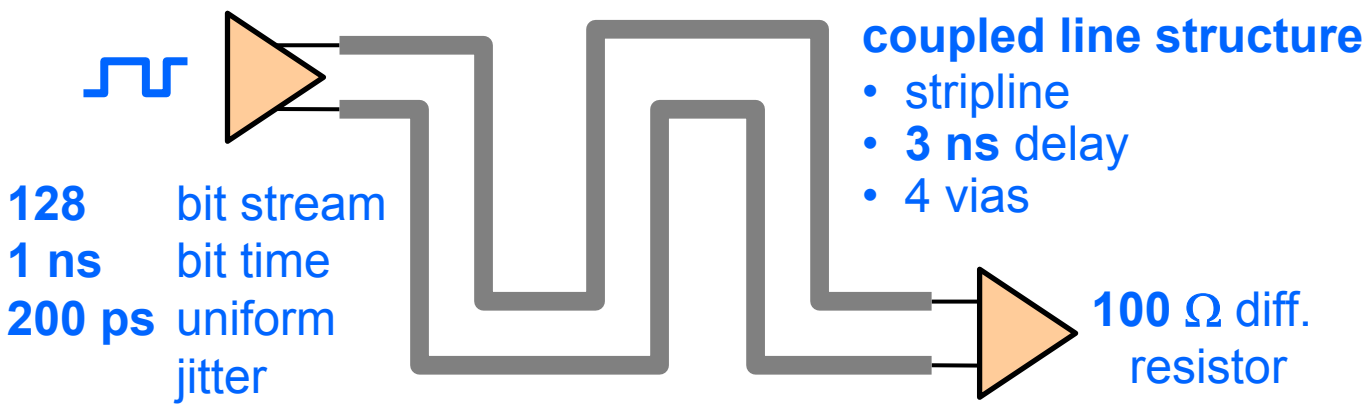
Fairchild FIN1001 (V_{dd}=3.3V) LVDS
High Speed Differential Driver

PARAMETRIC MODEL

Macromodel **details** and **validation** in

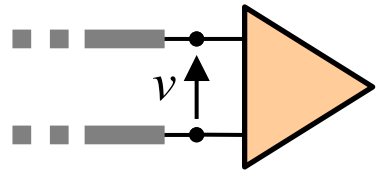
[I.S.Stievano, C.Siviero, I.A.Maio, F.G.Canavero, "Modeling of the Static and Dynamic Behavior of Differential Drivers," Proc. of EMC-Compo 2004, Mar. 31 – Apr. 1, 2004]

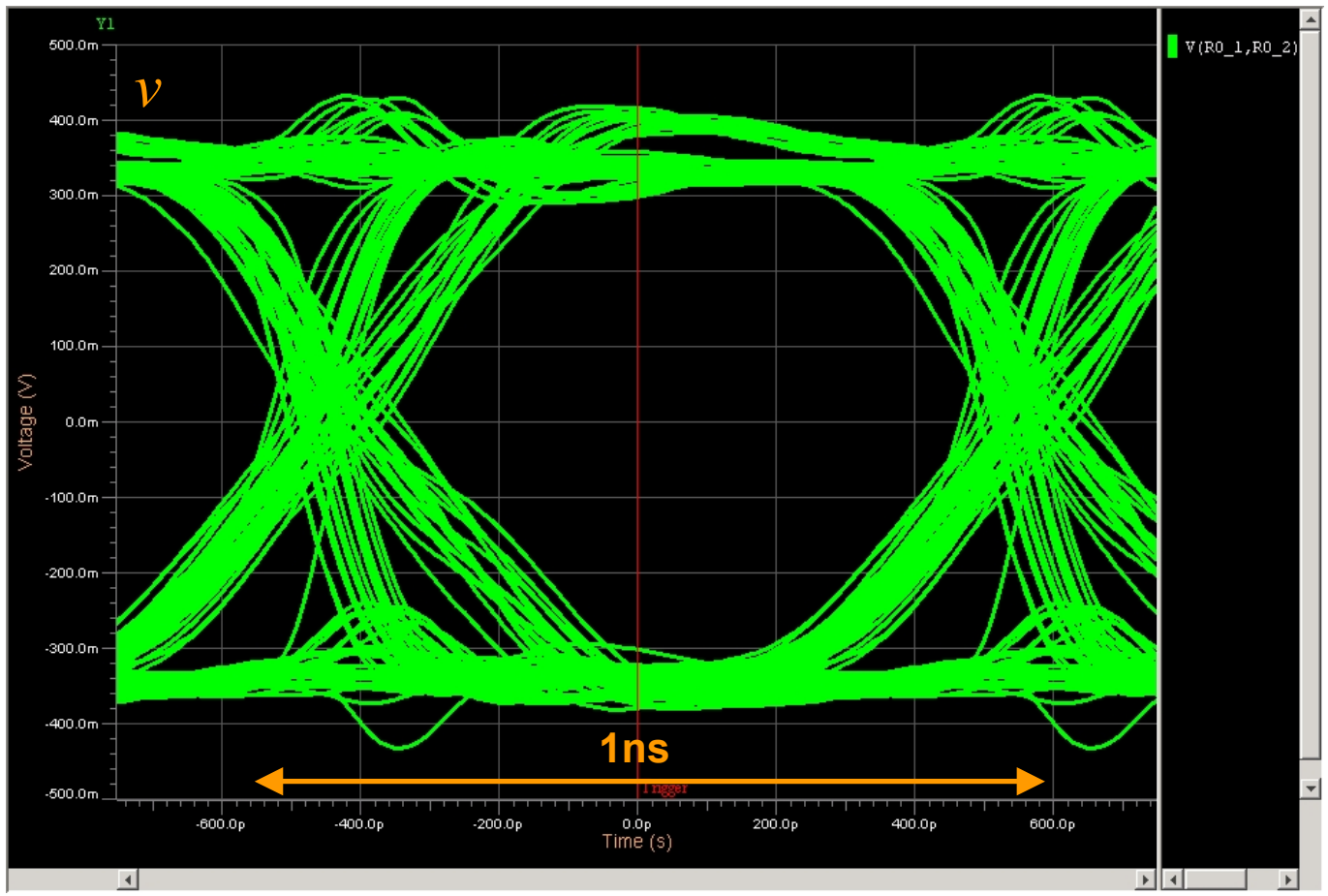
TEST CIRCUIT



Example 2 (ii)

ICX Application: Eye diagram





Conclusions

Parametric models are well suited to IBIS multilingual extension: easy implementation and use in IBIS compliant simulators

advantages

- **Math Foundations and Generality**
- **HIGH ACCURACY** at **LOW COMPLEXITY** **(like classical IBIS models)**
- **Good EFFICIENCY**
- **PROTECTION OF IP**

➢ **advanced modeling techniques introduced via IBIS multilingual extension not affect IBIS standard and require no upgrades of IBIS ver. 4.1 compliant simulators**

Acknowledgements

Thanks to

-  for providing the **ICX** simulation environment
- **Sergio Perazza** (Mentor, Italy) for the technical support on ICX and for the validation Example 2
- **Arpad Muranyi** (Intel) for VHDL templates and code posted on http://www.eda.org/pub/ibis/summits/jun03a/ and http://www.eda.org/pub/ibis/summits/feb04a/