SSTL_2 Modeling Experiences

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**Introduction**

- **SSTL_2** → Stub Series Terminated Logic for 2.5V

Vddq=2.5V

Vtt=0.5 x Vddq

Rser=250Ohms

Rpara=500Ohms

Z=50Ohms

Vref=0.5 x Vddq

SSTL_2 Class I symmetrically single parallel terminated output load and series resistor
Comparison of transistor level SPICE simulations with HSPICE B-Model behavioral simulations

SPICE based generation of one waveform and two waveform IBIS models

- One waveform: \( R_{\text{fixture}} = 50\Omega, V_{\text{fixture}} = V_{ccq}/2 = 1.25V \)
- Two waveform: \( R_{\text{fixture}} = 50\Omega, V_{\text{fixture}} = 0V \) and \( V_{\text{fixture}} = 2.5V \)

Comparison of both models for different loading conditions

- Case 1: parallel terminated tr-line (\( Z_0=50\Omega, td=1.5ns \); \( R_{\text{para}}=50\Omega \); \( V_{\text{term}}=1.25V \); \( C_{\text{load}}=2.5pF \)
- Case 2: unterminated tr-line (\( Z_0=50\Omega, td=1.5ns \); \( C_{\text{load}}=2.5pF \)
- Case 3: parallel and series terminated tr-line (\( Z_0=50\Omega, td=1.5ns \); \( R_{\text{ser}}=25\Omega \); \( R_{\text{para}}=50\Omega \); \( V_{\text{term}}=1.25V \); \( C_{\text{load}}=2.5pF \)

Model quality dependence on the assumption of the multiplier relationship
One Waveform Model
CASE 1: parallel terminated tr-line (Z0=50Ohms, td=1.5ns); Rpara=50Ohms; Vterm=1.25V; Cload=2.5pF

Node OUT: Transistor based Behavioral
Node END: Transistor based Behavioral
Two Waveform Model
CASE 1: parallel terminated tr-line (Z0=50Ohms, td=1.5ns); Rpara=50Ohms; Vterm=1.25V; Cload=2.5pF
Two Waveform Model
CASE 2: unterminated tr-line (Z0=50Ohms, td=1.5ns); Cload=2.5pF
One Waveform Model with Parameter $r/f_{wf}=0.1$

CASE 2: unterminated tr-line ($Z_0=50$Ohms, $t_d=1.5$ns); $C_{load}=2.5$pF
One Waveform Model with Parameter $r/f_{wf}=1$

CASE 2: unterminated tr-line ($Z_0=50\,\text{Ohms}, \, t_d=1.5\,\text{ns}); \, C_{load}=2.5\,\text{pF}$
One Waveform Model with Parameter $r/fwf=1$

CASE 3: parallel and series terminated tr-line ($Z_0=50\,\text{Ohms}, t_d=1.5\,\text{ns}$); $R_{\text{ser}}=25\,\text{Ohms}$; $R_{\text{para}}=50\,\text{Ohms}$; $V_{\text{term}}=1.25\,\text{V}$; $C_{\text{load}}=2.5\,\text{pF}$
Two Waveform Model
CASE 3: parallel and series terminated tr-line (Z0=50Ohms, td=1.5ns); Rser=25Ohms; Rpara=50Ohms; Vterm=1.25V; Cload=2.5pF
Kpu(t) and Kpd(t) Multiplier Relationships

HSPICE B-model St_pd(t) (green) and St_pu(t) (red) multiplier functions

Model types:

• One-waveform model
  Vt-tables for only 1 load condition per edge available. Arbitrarily assumption of the multiplier relationships
  • HSPICE B-model:
    ramp funktion for kpd(t) and kpu(t)
    ramp can be tuned by rwf/fwf parameters
  • Other assumption
    kpur(f(t)) + kpd(f(t)) = 1; function range: 0 to 1

• Two-waveform model
  Vt-tables for at least 2 load conditions available
  None assumption of the multiplier relationships
  kpur(f(t)) ; kpd(f(t)); function range: 0;1 to 1;0
One Waveform Model with \( k_{pu}(t) + k_{pd}(t) = 1 \)

CASE 2: unterminated tr-line (\( Z_0=50\text{Ohms}, \tau_d=1.5\text{ns} \); \( C_{load}=2.5\text{pF} \))
One and Two Waveform Model

CASE 2: unterminated tr-line (Z0=50Ohms, td=1.5ns); Cload=2.5pF

Node OUT:
- Transistor based
- 1W Behavioral
- 2W Behavioral

Node END:
- Transistor based
- 1W Behavioral
- 2W Behavioral
Conclusions

- Generation conditions: $R_{\text{fixture}} = 50\text{Ohms}$, $V_{\text{fixture}} = V_{ccq}/2 = 1.25\text{V}$: best results for single parallel terminated output load

- Generation conditions: $R_{\text{fixture}} = 50\text{Ohms}$, $V_{\text{fixture}} = 0\text{V}$ and $V_{\text{fixture}} = 2.5\text{V}$: best results for unterminated output load

- Model quality of „One Waveform“ models strongly depends on loading conditions and assumption of multiplier relationship

- IBIS models with golden waveforms are a real need to check the quality
  - of the tool dependent behavioral models
  - in case of real world application conditions