



# **Accuracy of IBIS models with reactive loads**

---

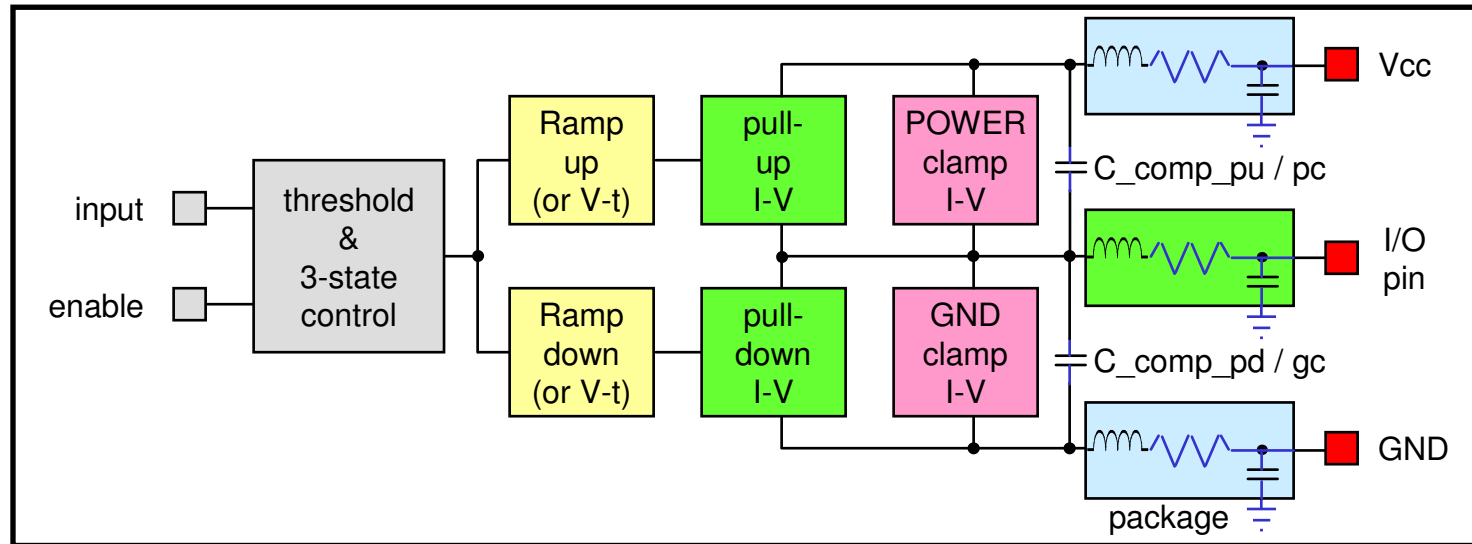
**Arpad Muranyi**  
**Signal Integrity Engineering**

**March 10, 2006**





# IBIS model block diagram

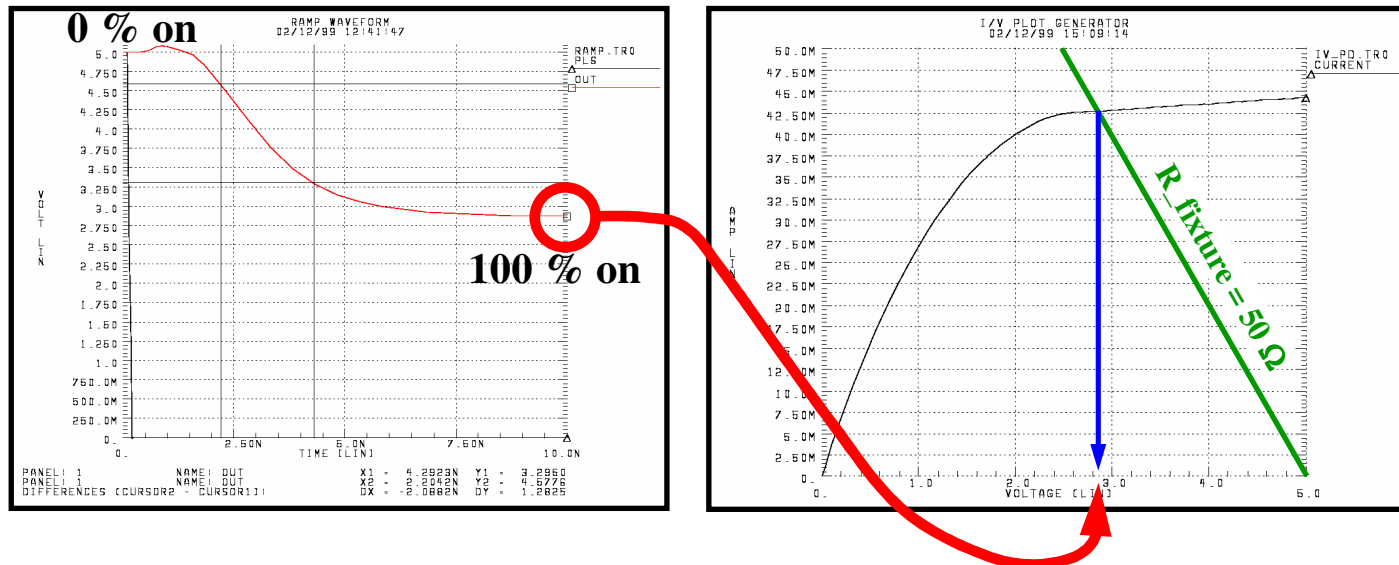


- The I-V curves represent the fully ON or OFF DC characteristics of the buffer
- The V-t curves represent the transient switching characteristics of the buffer
- The V-t curves are used to make up what is missing between the fully ON/OFF I-V curves





# I-V curves during transients

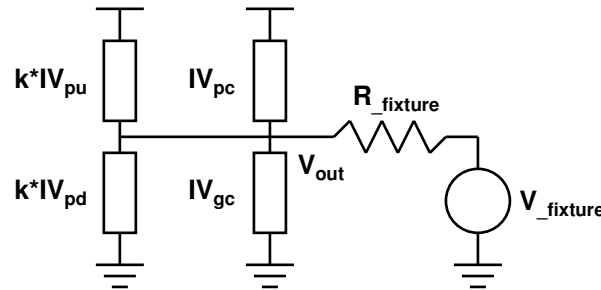


- V-t curves can be used as time variant scaling coefficients for the I-V curves to generate partially ON I-V curves during transitions
- The V-t curves can be converted to K-t curves to be used in the IBIS model algorithm





# The 2EQ/2UK buffer algorithm



$$0 = k_{pu}(t) \cdot IV_{pu}(V_{wfm1}(t)) + IV_{pc}(V_{wfm1}(t)) - k_{pd}(t) \cdot IV_{pd}(V_{wfm1}(t)) - IV_{gc}(V_{wfm1}(t)) - I_{out}(V_{wfm1}(t))$$

$$0 = k_{pu}(t) \cdot IV_{pu}(V_{wfm2}(t)) + IV_{pc}(V_{wfm2}(t)) - k_{pd}(t) \cdot IV_{pd}(V_{wfm2}(t)) - IV_{gc}(V_{wfm2}(t)) - I_{out}(V_{wfm2}(t))$$

where

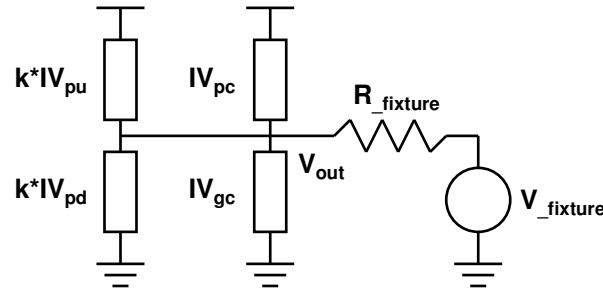
$$I_{out} = \frac{V_{out} - V_{fixture}}{R_{fixture}}$$

and wfm1 and wfm2 are waveforms of the same switching direction (rising edges or falling edges) obtained with two different  $V_{fixture}$  values (usually Vcc and GND)





# Solving for $K_{pd}$ and $K_{pu}$



$$0 = k_{pu} \cdot I_{pu1} + I_{pc1} - k_{pd} \cdot I_{pd1} - I_{gc1} - I_{out1}$$

$$0 = k_{pu} \cdot I_{pu2} + I_{pc2} - k_{pd} \cdot I_{pd2} - I_{gc2} - I_{out2}$$

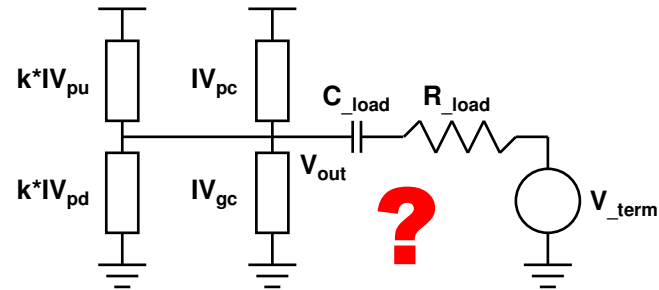
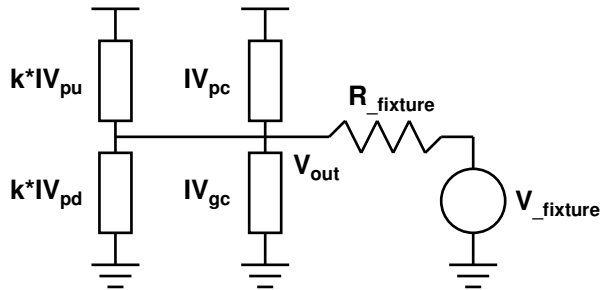
$$k_{pd} = \frac{I_{pu2} \cdot (I_{out1} + I_{gc1} - I_{pc1}) + I_{pu1} \cdot (I_{pc2} - I_{gc2} - I_{out2})}{I_{pd2} \cdot I_{pu1} - I_{pd1} \cdot I_{pu2}}$$

$$k_{pu} = \frac{I_{pd2} \cdot (I_{out1} + I_{gc1} - I_{pc1}) + I_{pd1} \cdot (I_{pc2} - I_{gc2} - I_{out2})}{I_{pd2} \cdot I_{pu1} - I_{pd1} \cdot I_{pu2}}$$





# Problem statement



$$0 = k_{pu}(t) \cdot IV_{pu}(V_{wfm1}(t)) + IV_{pc}(V_{wfm1}(t)) - k_{pd}(t) \cdot IV_{pd}(V_{wfm1}(t)) - IV_{gc}(V_{wfm1}(t)) - I_{out}(V_{wfm1}(t))$$

$$0 = k_{pu}(t) \cdot IV_{pu}(V_{wfm2}(t)) + IV_{pc}(V_{wfm2}(t)) - k_{pd}(t) \cdot IV_{pd}(V_{wfm2}(t)) - IV_{gc}(V_{wfm2}(t)) - I_{out}(V_{wfm2}(t))$$

where

$$I_{out} = \frac{V_{out} - V_{fixture}}{R_{fixture}}$$

**dV/dt and/or dI/dt are missing from this equation**

**The current of the capacitor is**  
 **$I = C \cdot dV/dt$**

**The voltage of an inductor is**  
 **$V = L \cdot dI/dt$**

$$I_{out} \neq \frac{V_{out} - V_{fixture}}{R_{fixture}}$$





# Additional considerations

- The 2EQ/2UK algorithm is only “in effect” during transitions (within the V-t curve length)
- After that, the model is in steady state, so the only thing that matters is its I-V curve (and C\_comp)
- The interaction between static I-V curves and reactive loads is usually accurate
- C\_comp does provide some “dynamic” characteristics, but that is not the same as scaling the I-V curves during transitions



\*Other brands and names are the property of their respective owners





# Conclusions

- The stronger the influence of a reactive load is on the output current **during switching transients**, the less accurate the results of the 2EQ/2UK algorithm may be
- Since there are several effects interacting together it is difficult to make precise predictions about the accuracy of the model
  - The relative size of the reactive load, buffer strength, V-t curve length and C\_comp can make a big difference in the outcome
- We do not know what algorithm is used in tools
- Encourage implementation of better algorithms in tools if needed, or develop a solution in \*-AMS



\*Other brands and names are the property of their respective owners

