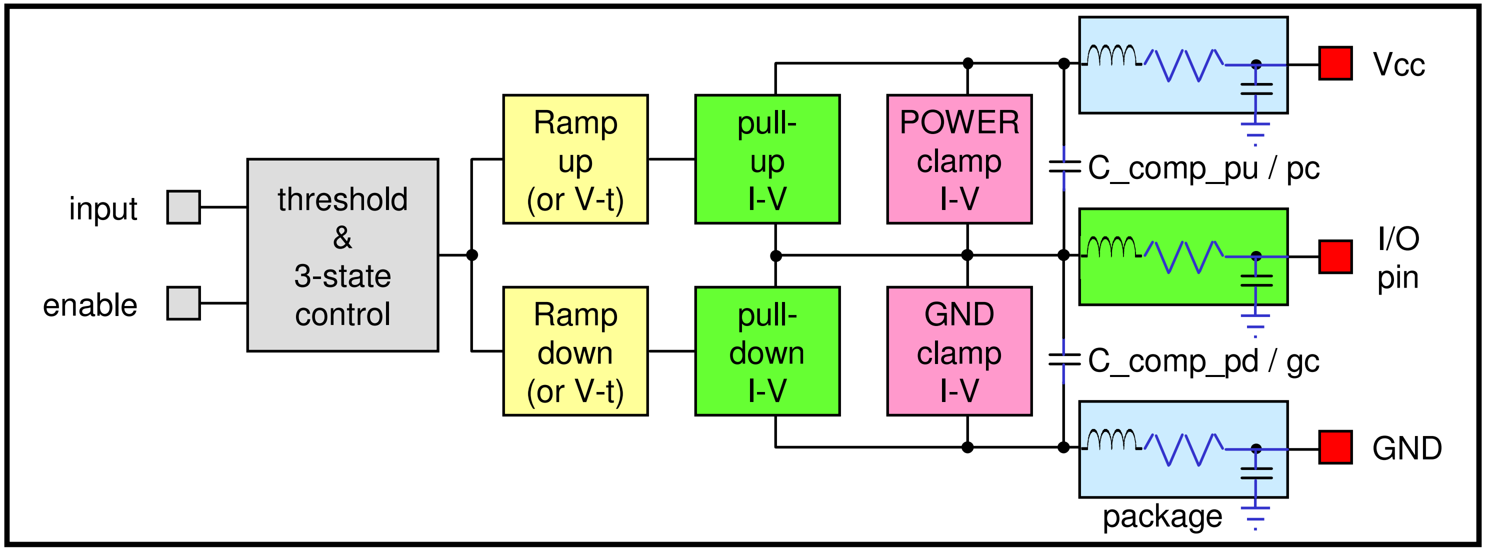
Accuracy of IBIS models with reactive loads

Arpad Muranyi
Signal Integrity Engineering

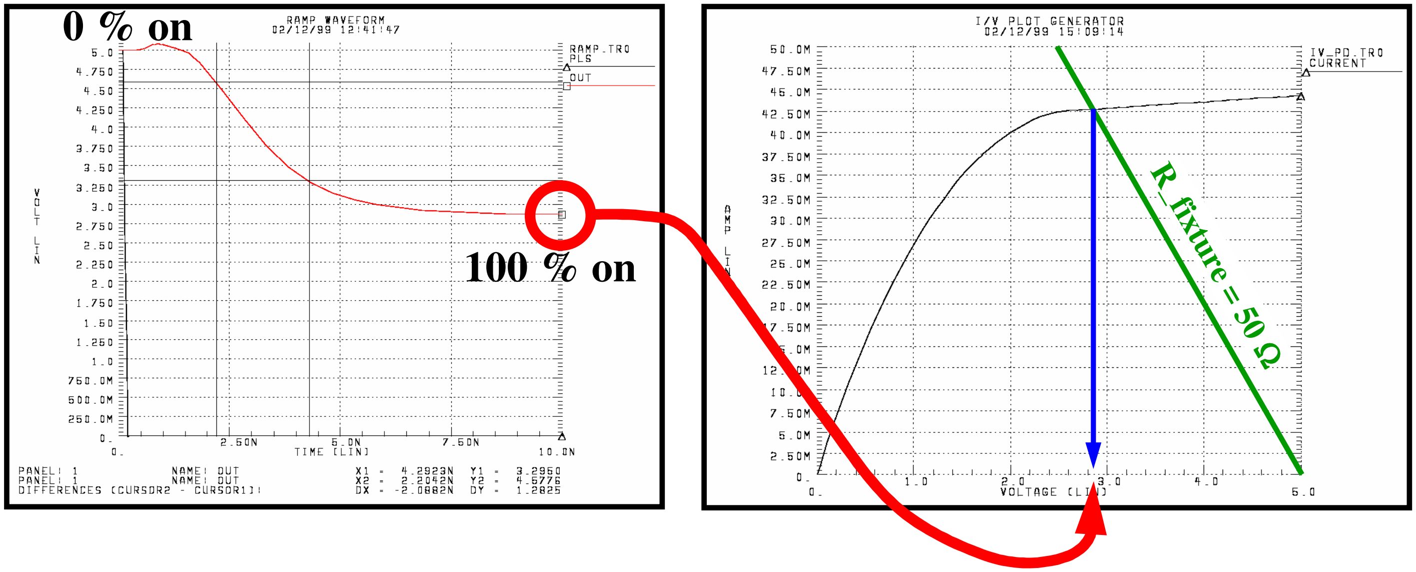
February 9, 2006

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**

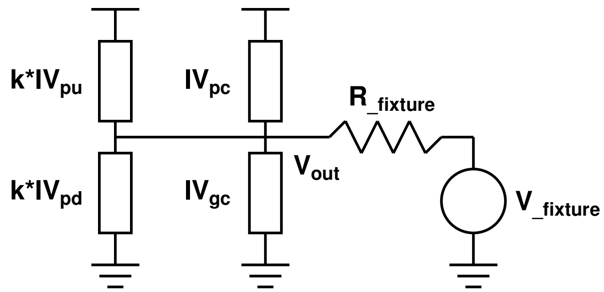
I-V curves during transients



- **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**

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

The 2EQ/2UK buffer algorithm



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

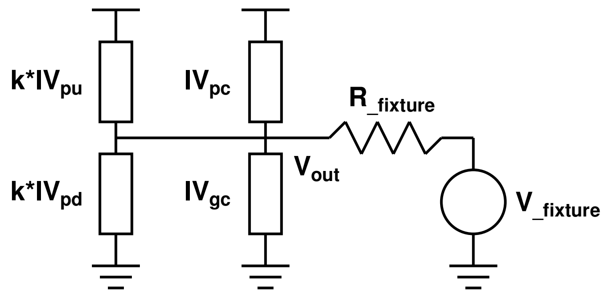
$$0 = k_{pu}(t)\cdot IV_{pu}(V_{wfm2}(t)) + IV_{pc}(V_{wfm2}(t)) - k_{pd}(t)\cdot IV_{pd}(V_{wfm2}(t)) - IV_{gc}(V_{wfm2}(t)) - I_{out}(V_{wfm2}(t))$$

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}



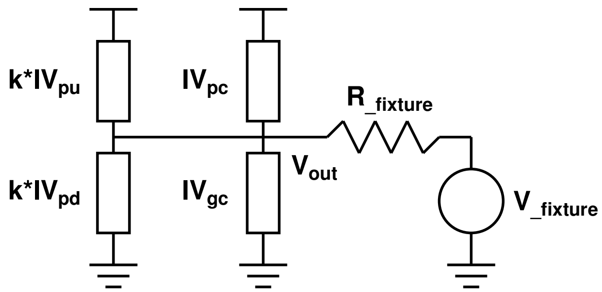
$$0 = k_{pu} \cdot I_{pu1} + I_{pc1} - k_{pd} \cdot I_{pd1} - I_{gc1} - I_{out1}$$

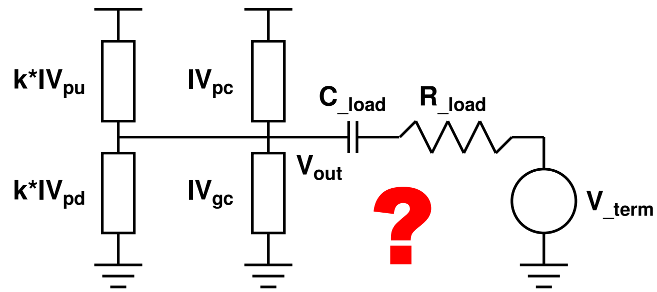
$$0 = k_{pu} \cdot I_{pu2} + I_{pc2} - k_{pd} \cdot I_{pd2} - I_{gc2} - I_{out2}$$

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

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

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*dV/dt

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

$$Iout \neq \frac{Vout - Vfixture}{Rfixture}$$

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

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