Accuracy of IBIS models with reactive loads

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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

\[ I_{out} = \frac{V_{out} - V_{\text{fixture}}}{R_{\text{fixture}}} \]

and wfm1 and wfm2 are waveforms of the same switching direction (rising edges or falling edges) obtained with two different \( V_{\text{fixture}} \) 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_{wf1}(t)) + IV_{pc}(V_{wf1}(t)) - k_{pd}(t) \cdot IV_{pd}(V_{wf1}(t)) - IV_{gc}(V_{wf1}(t)) - I_{out}(V_{wf1}(t))

0 = k_{pu}(t) \cdot IV_{pu}(V_{wf2}(t)) + IV_{pc}(V_{wf2}(t)) - k_{pd}(t) \cdot IV_{pd}(V_{wf2}(t)) - IV_{gc}(V_{wf2}(t)) - I_{out}(V_{wf2}(t))

where

\[ I_{out} = \frac{V_{out} - V_{fixture}}{R_{fixture}} \]

The current of the capacitor is
\[ I = C \cdot \frac{dV}{dt} \]

The voltage of an inductor is
\[ V = L \cdot \frac{dl}{dt} \]

\[ I_{out} \neq \frac{V_{out} - V_{fixture}}{R_{fixture}} \]

dV/dt and/or dl/dt are missing from this equation

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