More Details on True Differential Buffer Characterization

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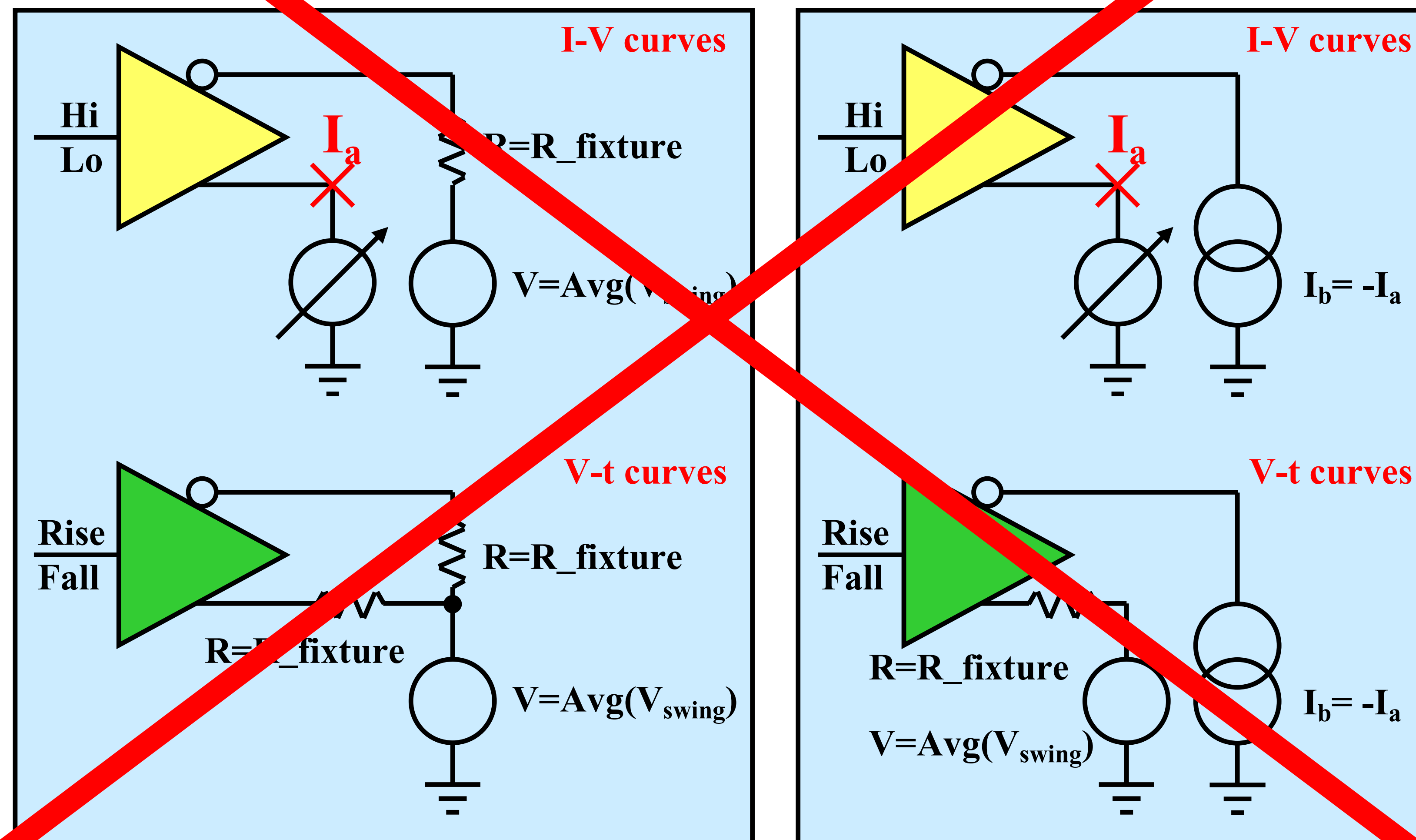
Background

- **The author of this presentation introduced a page on true differential buffers in his "Introduction to IBIS Models and IBIS Model Making" class materials in September 2000**
  - a proprietary LVDS buffer was used to make recommendations for generating IV and Vt curves to convert it to an IBIS model
  - the buffer used in this example did not have on-die termination
- **Hazem Hegazy gave two presentations in January and March 2001 at IBIS summits on this subject**
  - quoting the above class material, some shortcomings of the suggested technique were pointed out and explained by Hazem
    - models of buffers with on-die termination made this way are inaccurate
    - miscorrelation with original SPICE model under different loading conditions
  - new techniques were demonstrated giving better correlation with the original SPICE model, Proposal-III being the best and most accurate

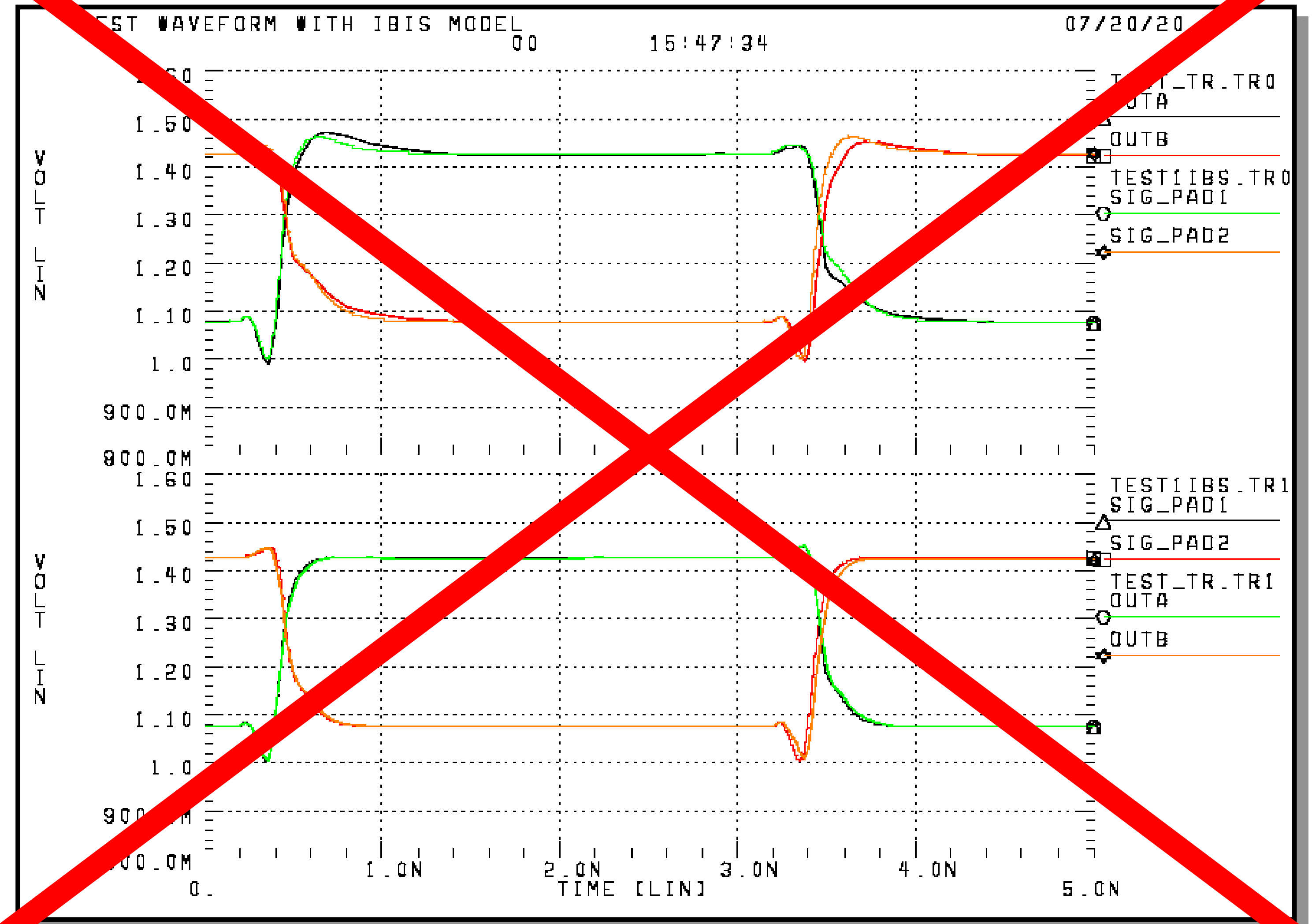
True differential buffers (LVDS)

IBIS doesn't support them directly but they can be approximated with two different methods



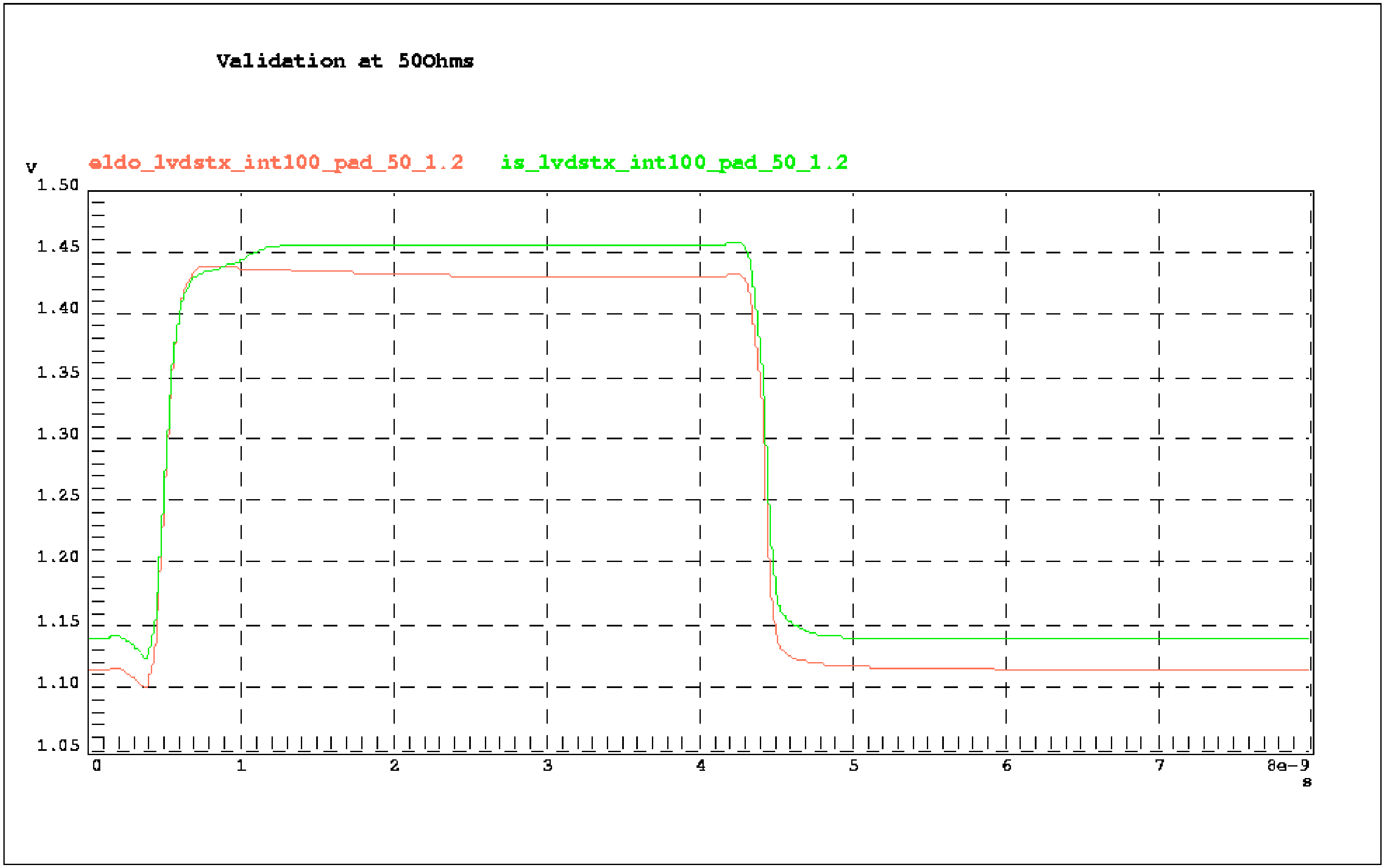
* A. Muranyi "Introduction to IBIS Models and IBIS Modeling", September 2000, p. 87.

LVDS SPICE and IBIS model overlay



* A. Muranyi “Introduction to IBIS Models and IBIS Modeling”, September 2000, p. 88.

Miscorrelation of original technique



* H. Hegazy and Mohammed Korany "LVDS Modeling", IBIS Summit, March 2001, p. 14.

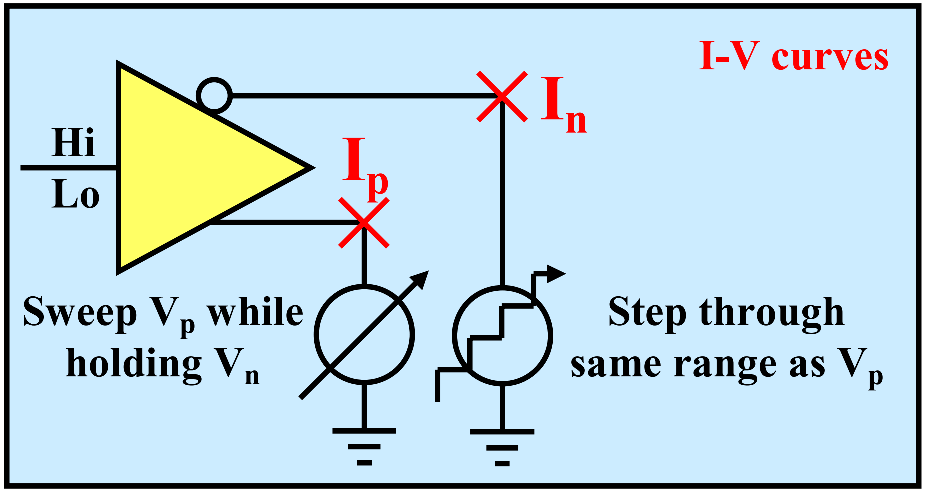
Motivation for this study

- **Hazem's Proposal-III essentially introduces the idea of measuring the common and differential currents of the buffer separately**
  - great idea, similar to RLGC matrices of T-lines having self and mutual entries leading to common and differential impedance (not the same as *common mode* and *differential mode* impedance, see references)
  - the concept of common and differential impedance is well known and understood
- **Intentional or not, differential buffers also have common and differential currents (or impedance)**
  - if intentional, this can be from on-die terminations, etc…
  - if not intentional, this can be caused by the non ideal characteristics of current sources, leakages, etc…
- **Proposal-III, however, is lacking generality for measuring the differential portion of the output currents**

True differential buffers with IBIS v3.2

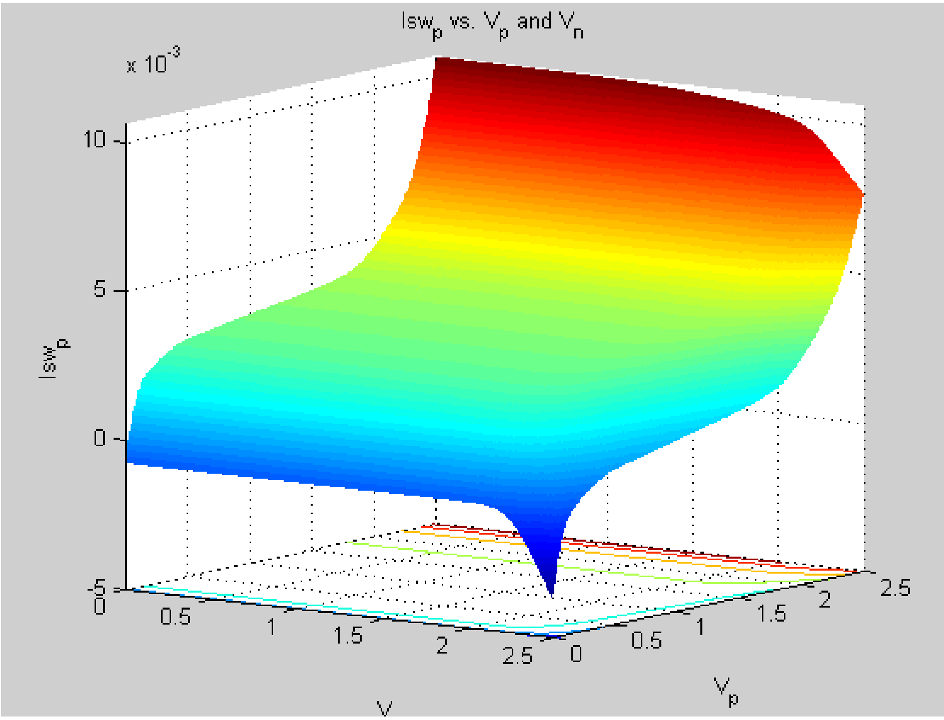
- **[Series Pin Mapping]**
  - allows the mapping of series elements, such as R, L, C and current tables to pins which *already have* a [Model] assignment
  - a series current (and/or) R, C elements could be used to account for the *differential currents*
  - the regular [Model] associated with the same two pins could be used to account for the *common currents*
- **[Series Current]**
- **[Series MOSFET]**
- **[R Series]**
- **[C Series]**
- **[Rc Series]**

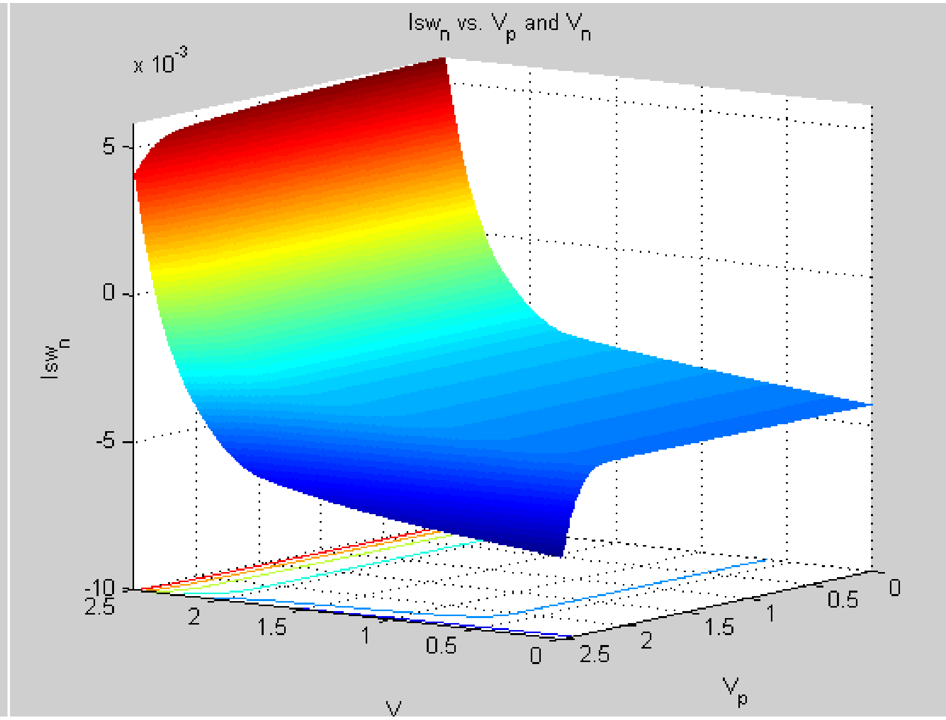
New IV curve measurement setup



- **When Vp = Vn we are measuring the common current**
- **When Vp ≠ Vn we are measuring the common plus differential currents**
- **To get the differential current alone we need to subtract the common current from the total current (i.e. normalize along the diagonal)**

IV surface of measured (total) currents



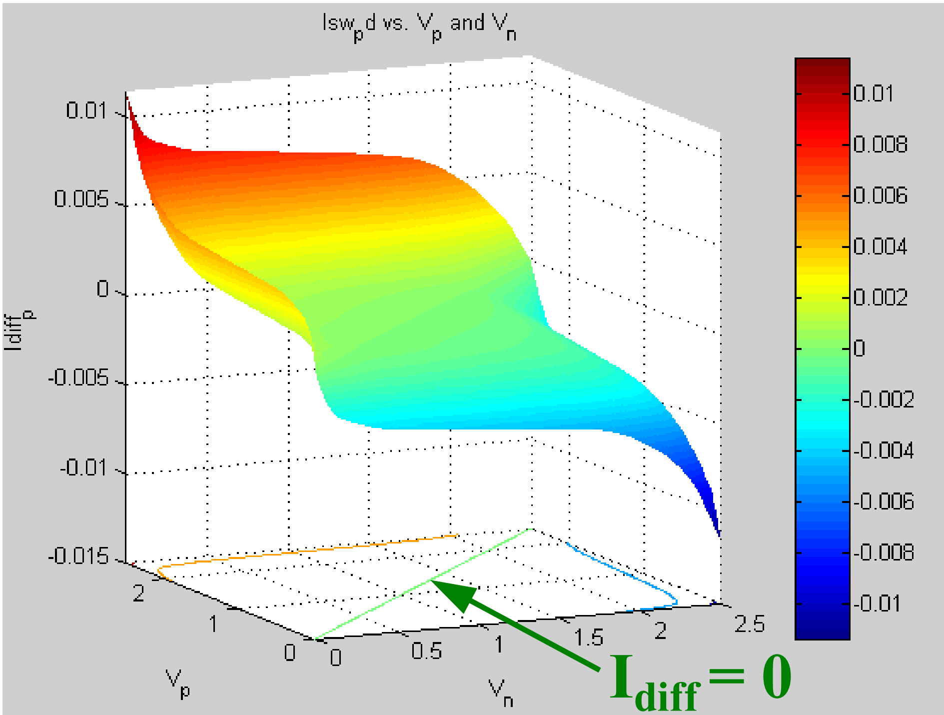


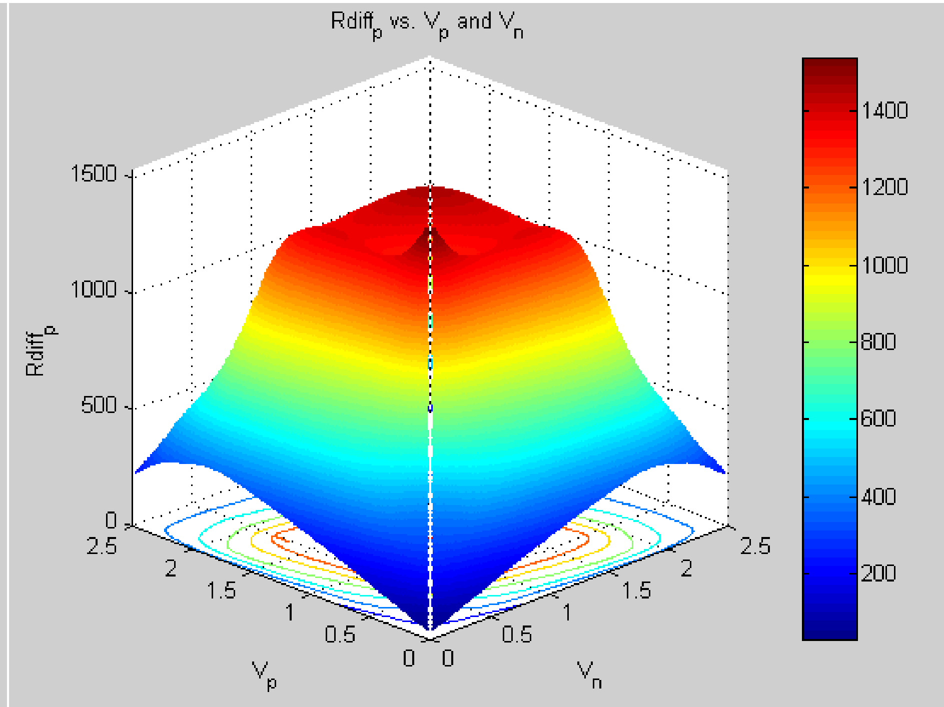
I_p vs. V_p and V_n (low state)

I_n vs. V_p and V_n (high state)

Differential buffer in drive mode without a 100 Ω parallel resistor

Differential IV curve and impedance



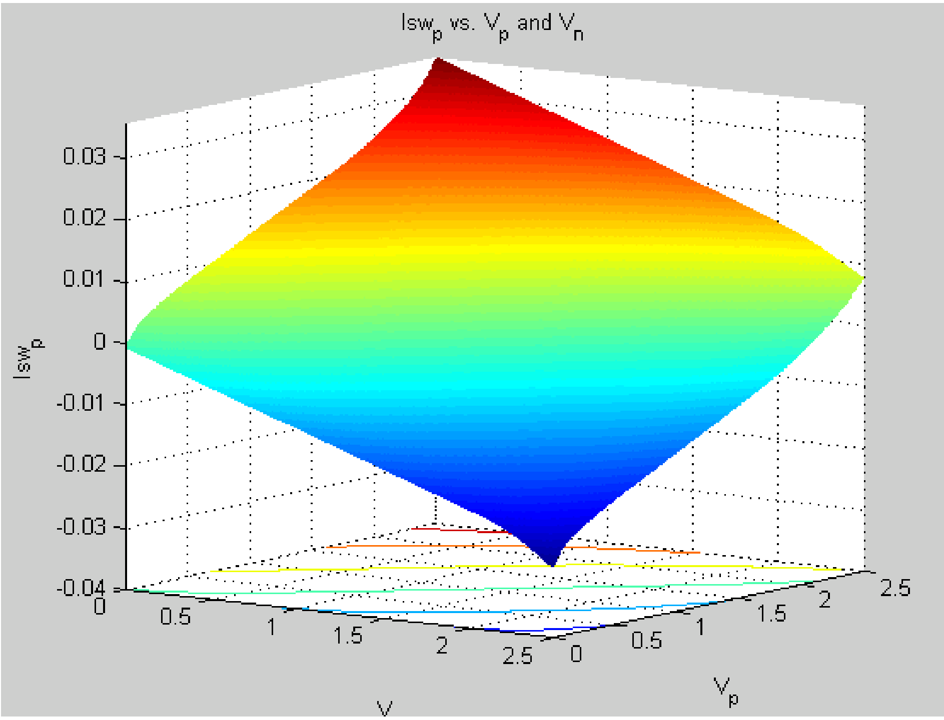


Differential current (when V_p is low)

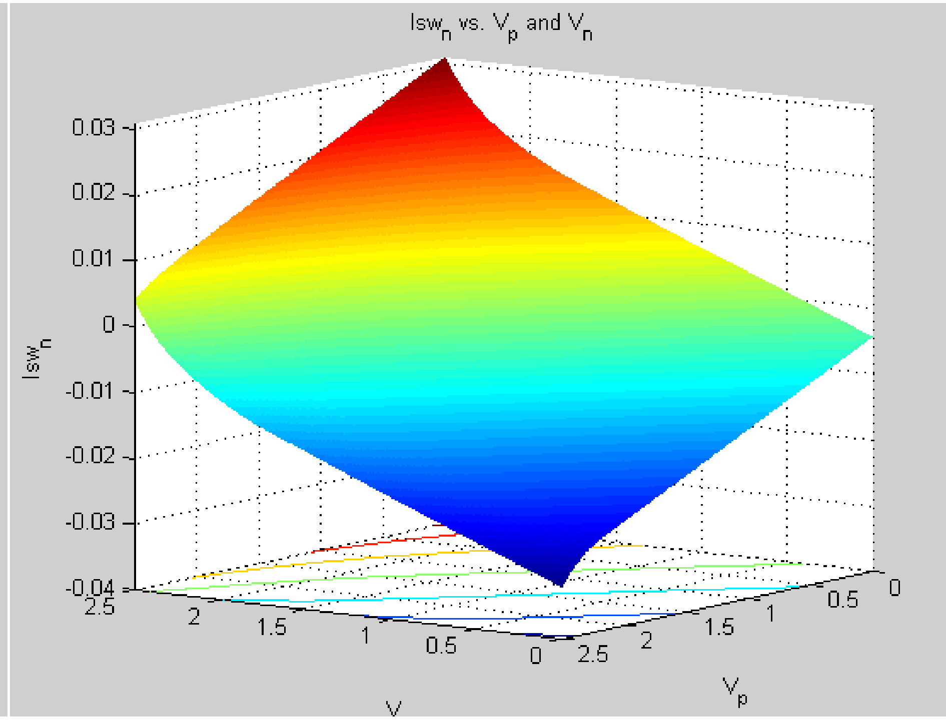
Differential impedance (when V_p is low)

Differential buffer in drive mode without a 100 Ω parallel resistor

IV surface of measured (total) currents



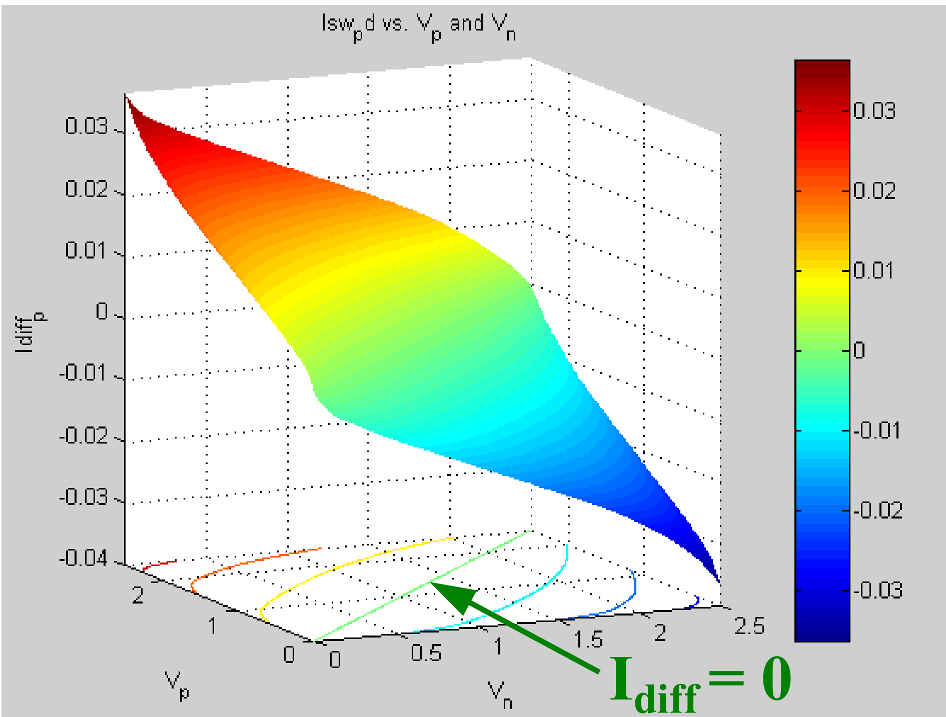
I_p vs. V_p and V_n
(low state)

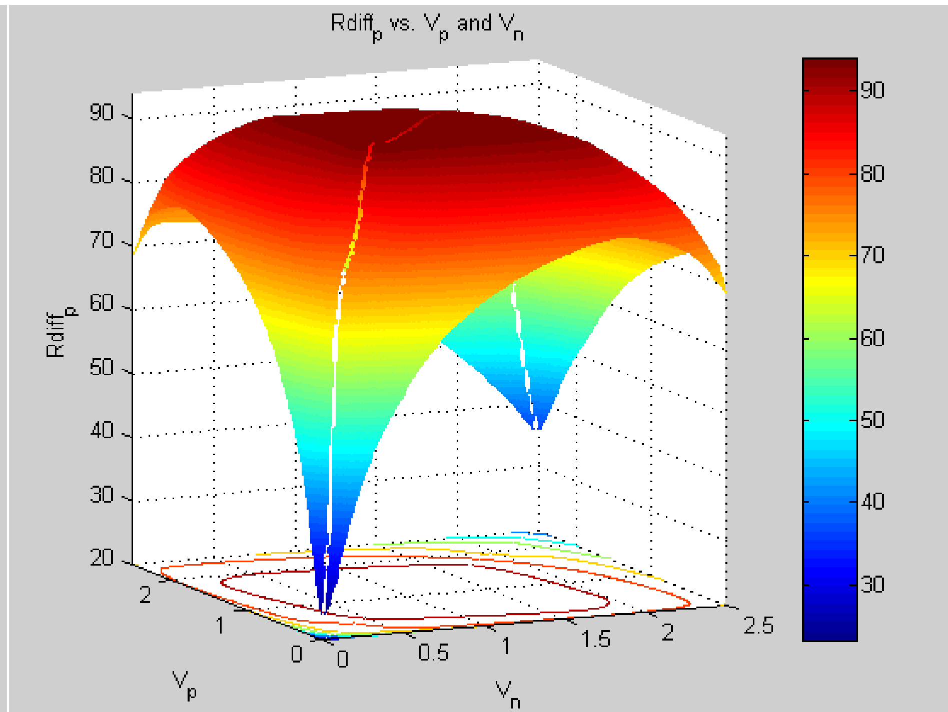


I_n vs. V_p and V_n
(high state)

Differential buffer in drive mode with a 100 Ω parallel resistor

Differential IV curve and impedance



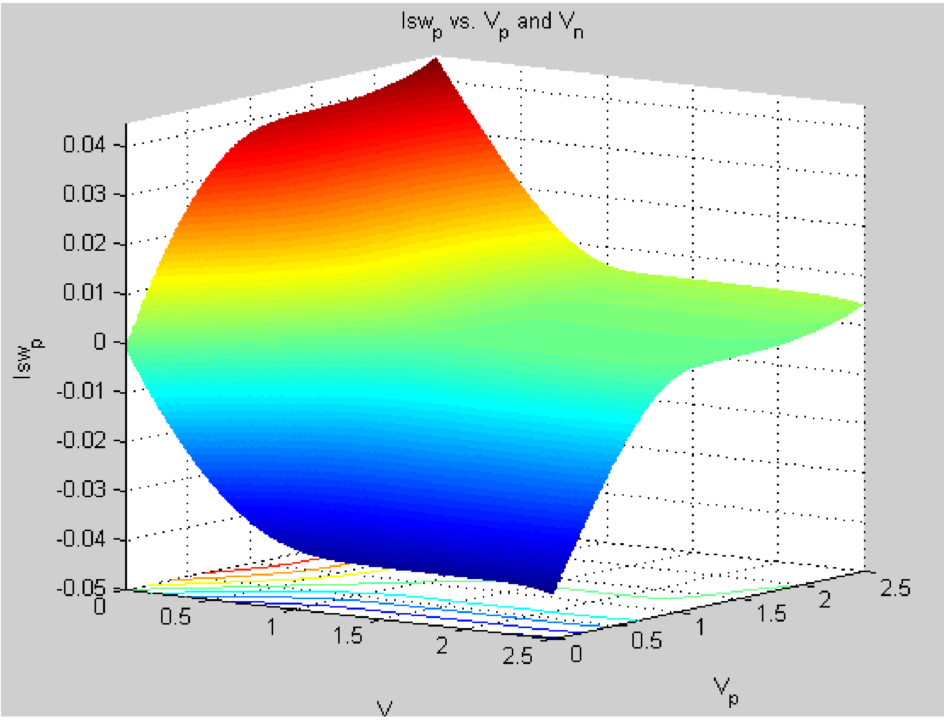


Differential current (when V_p is low)

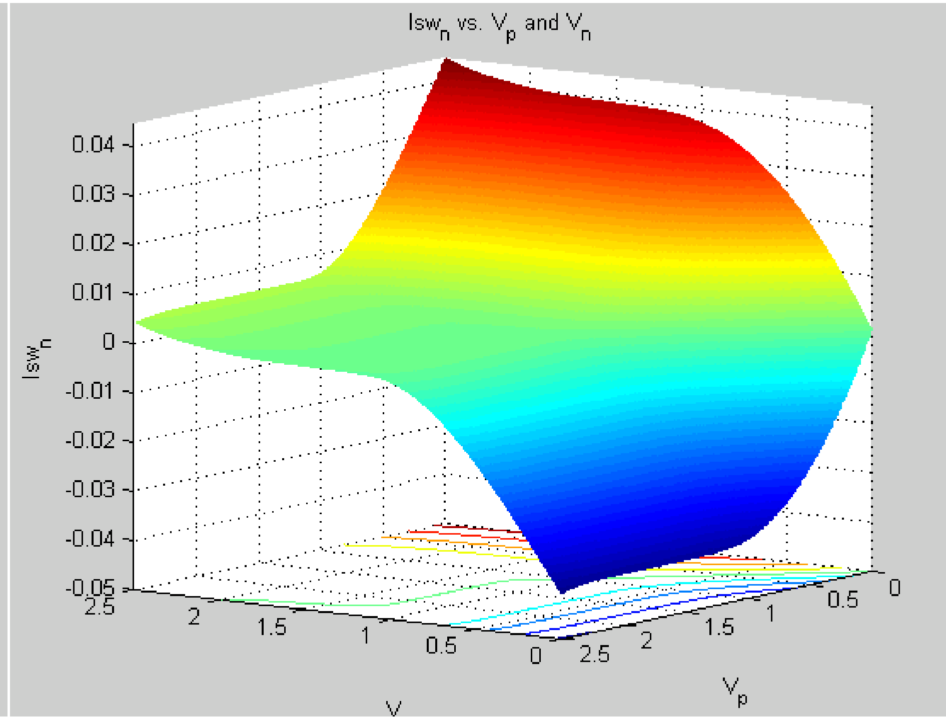
Differential impedance (when V_p is low)

Differential buffer in drive mode with a 100 Ω parallel resistor

IV surface of measured (total) currents



I_p vs. V_p and V_n
(low state)



I_n vs. V_p and V_n
(high state)

Differential buffer in receive mode without a 100 Ω parallel resistor

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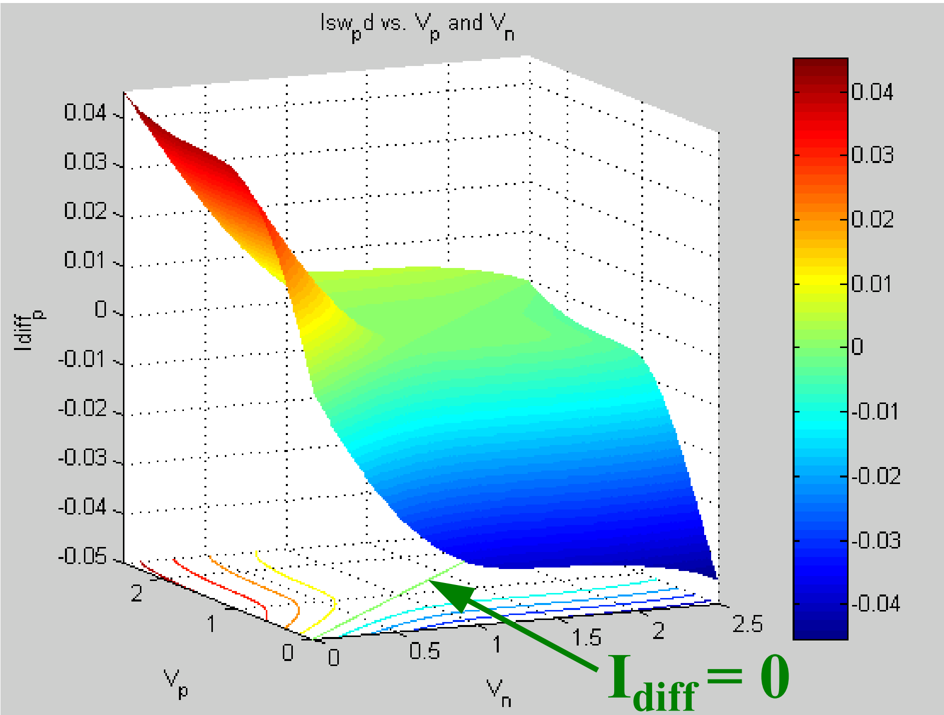
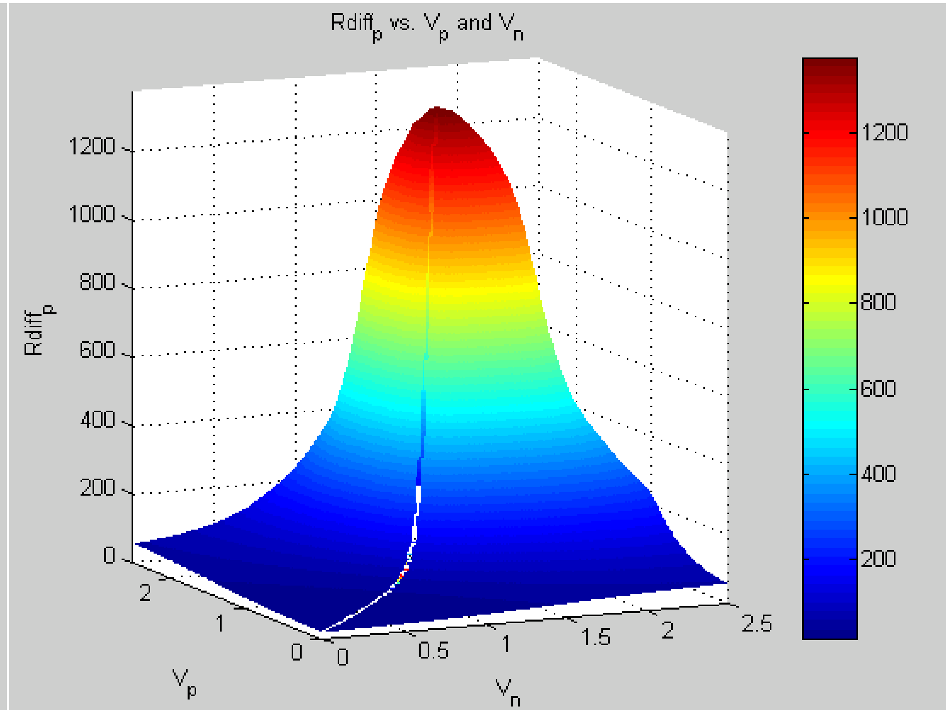
Differential IV curve and impedance



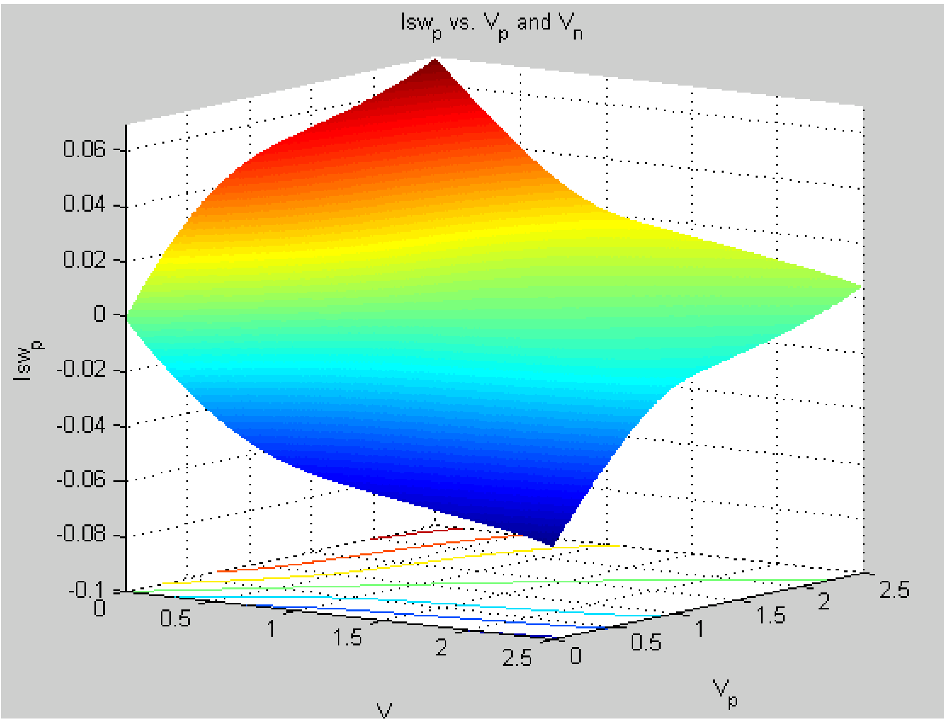


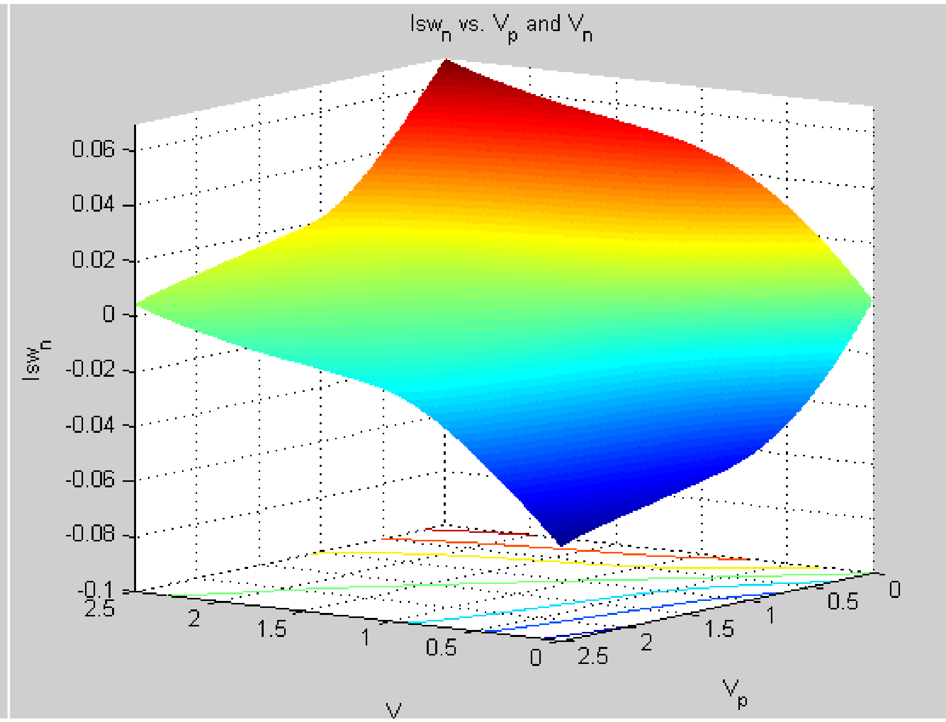
Differential current (when V_p is low)

Differential impedance (when V_p is low)

Differential buffer in receive mode without a 100 Ω parallel resistor

IV surface of measured (total) currents





I_p vs. V_p and V_n
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Differential buffer in receive mode with a 100 Ω parallel resistor

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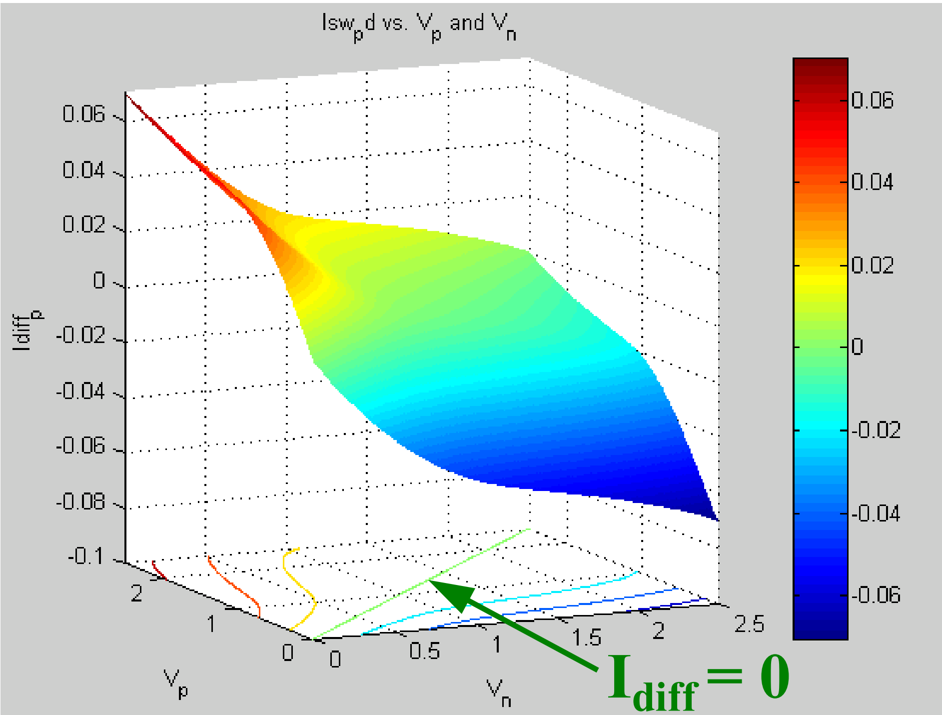
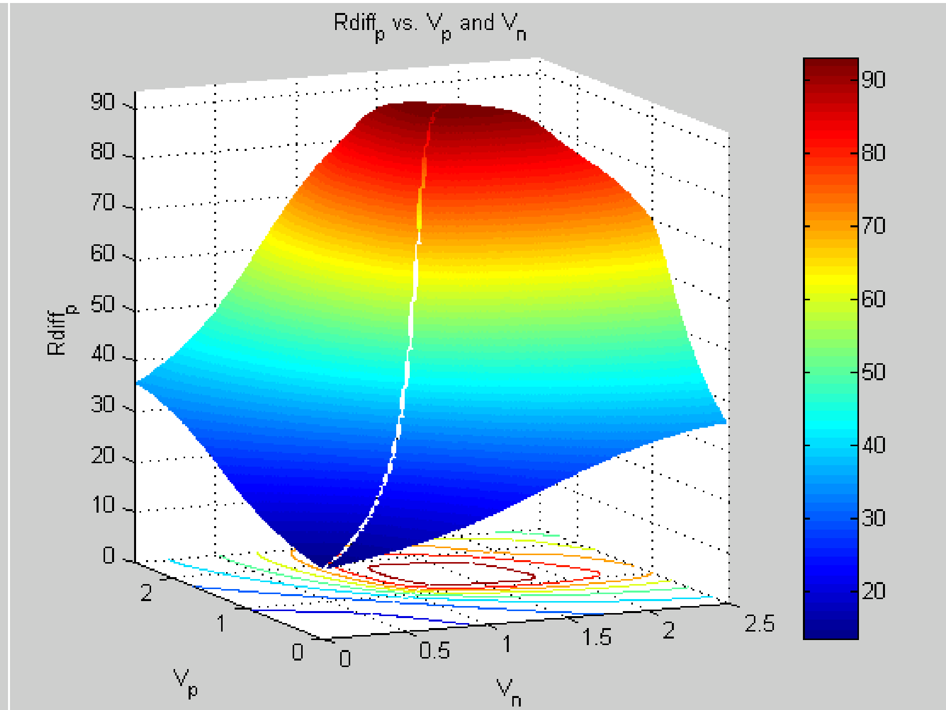


Differential current
(when V_p is low)



Differential impedance
(when V_p is low)

Differential buffer in receive mode with a 100 Ω parallel resistor

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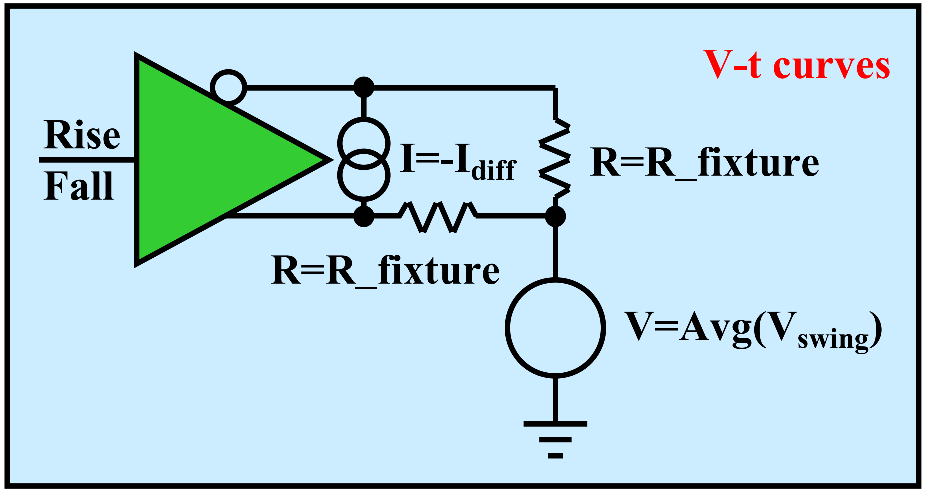
Conclusion

- **As seen on the previous plots, the differential current is a function of the voltages on the two I/O pins**
  - a complete description would require a multi dimensional current table
- **However, the normal operating region (where the signaling occurs) could be approximated with one of the available keywords with reasonable accuracy**
  - if the operating region includes strongly non linear shapes, this technique will need to rely on BIRD75 features

Further study and work needed

- **This concept needs to be proven with examples**
  - this could be done in the near future
- **Need to develop a differential C_meter to measure capacitive coupling between pins**
  - [C Series] can be used to hold this value in the IBIS model
- **More experiments need to be done to find out how the differential current varies with respect to time during transitions from one state to another**
  - do we need Vt curves for these differential elements also?
- **Simulation tool vendors should implement the series element features in IBIS v3.2 ASAP!**
  - unfortunately not all tools support these v3.2 keywords yet

Questions on Vt curve measurements



- If the differential currents are constant during transitions, we can cancel them by placing an equal and opposite sign current source between the pins, so that the Vt curves represent the time dependency of the common currents alone
- However, if the differential currents are time varying, we may need a more elaborate method to extract Vt curves for the common and differential currents independently (TBD)

References

- Steve Kaufer and Kellee Crisafulli, "Terminating Differential Signals on PCBs", Printed Circuit Design, March 1999
- Douglas Brooks, "Differential Impedance", Printed Circuit Design, August 1998
- Eric Bogatin, "Differential Impedance Finally Made Simple" Bogatin Enterprises, updated May 31, 2002, (www.BogatinEnterprises.com)