

# IO Buffer Reference Terminal

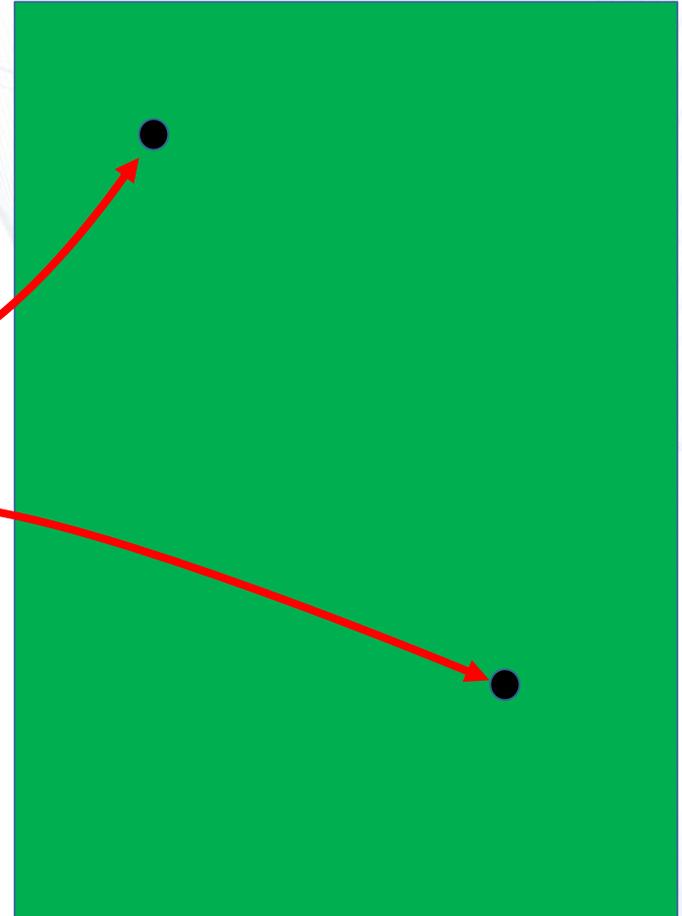
Walter Katz  
IBIS ATM  
June 7, 2016

# Ideally...

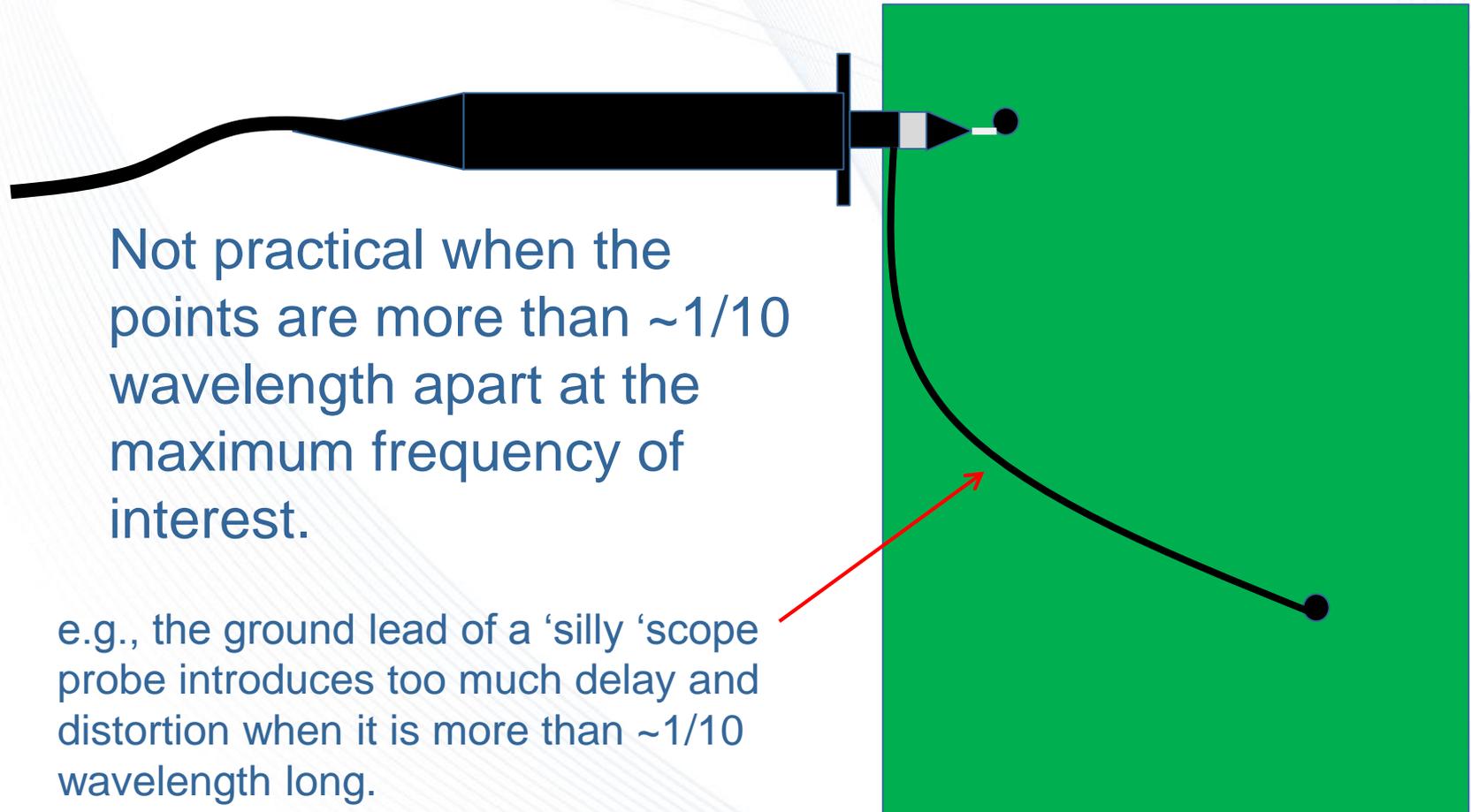
Subject to the limits defined by the Heisenberg Uncertainty Principle:

At any given instant in time there can be a difference in electrostatic potential between

- this point
- and
- this point



# However, measuring it...



Not practical when the points are more than  $\sim 1/10$  wavelength apart at the maximum frequency of interest.

e.g., the ground lead of a 'silly' scope probe introduces too much delay and distortion when it is more than  $\sim 1/10$  wavelength long.

In principle, we could combine multiple measurements that each individually span  $1/10$  wavelength; however, that's not practical under normal conditions.

# So...

**Anything that's not practical to measure had better not be relevant to a real system.**

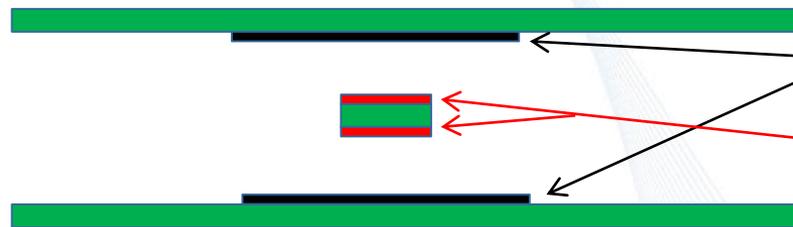
Apply this conclusion to the concept of a difference in electrostatic potential between a circuit node and a single point ground.

# Different Concept: Current Return Path

At frequencies above ~20MHz (conductors multiple skin depths thick) return current always flows as close as possible to signal current.

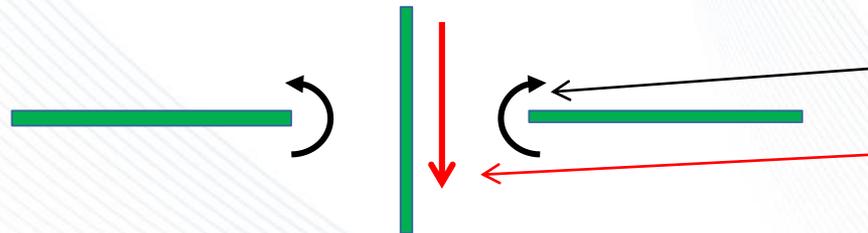
Examples:

stripline



Magnetic fields force return current to flow directly above/below signal current.

via

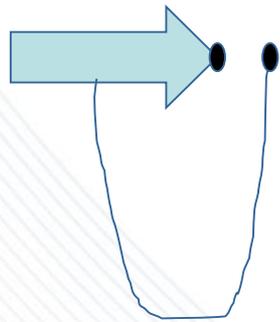


Magnetic fields force antipad current to exactly cancel via barrel current.

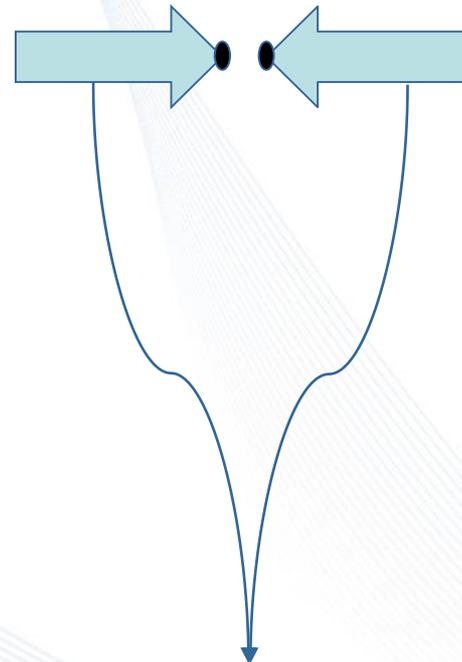
***Current return path is always close to signal path  
(and therefore is always directly relevant).***

During simulation, the voltage between two close points can be made with a single probe, or taking the difference of the voltage between each of the points and a common node (e.g. Node 0)

Single Probe



Two Probes



# Ground, GND, Node 0, Absolute Ground Make No Logical Sense Today

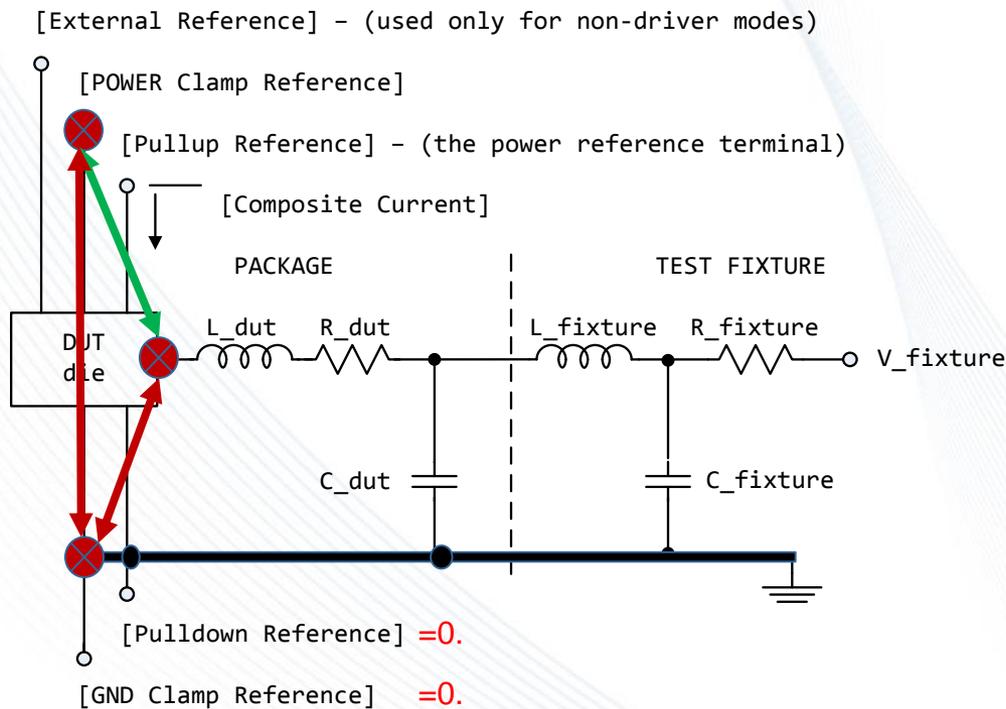
- While simulators have a reference Node 0, and IBIS and Data Sheets often talk about Ground, these are terms that have no logical application to today's high speed power and signal integrity.
- Correct terminology is Return Path
- So Model\_type "GND" should be "Return"
- [GND Clamp] should be [Return Clamp]
- [GND Clamp Reference] should be [Return Clamp Reference]
- Gnd\_clamp\_ref should be Return\_clamp\_ref
- And so on ...
  
- We are not going to change GND and Ground to Return in IBIS, but we must keep on reminding ourselves that there is no such thing as Ground which can be used to make reliable measurements.

# The only measurements that make sense at an I/O buffer are voltages between the terminals of an I/O buffer

If a terminal of an I/O buffer is connected to the Return Path node of a Test Fixture for Devices Under Test (DUT) then all measurement thresholds are voltages relative to this I/O buffer terminal. This shall be called the “DUT Reference Terminal”.

When the device is used in general simulations, then all voltages at the I/O buffer are also relative to this “DUT Reference Terminal”.

# When [Pulldown Reference] =0.0 and [GND Clamp Reference] =0.0 they are the Reference Node for all DUT Measurement and Thresholds



Note that the two red measurements are sufficient to determine the green measurement



# New [Model] Subparameter DUT\_ref\_term

This new subparameter is optional and defines the rail terminal that should be used by the simulator as the reference terminal for all voltage measurements at of the buffer model.

It has the following allowed values (\*\_ref)

- Pulldown\_ref
- Gnd\_clamp\_ref
- Pullup\_ref
- Power\_clamp\_ref

# If [\* Reference] != 0.0V

If the value of [\* Reference] for the [DUT Reference Terminal] is not 0.0V, then the voltages measured referenced to \*\_ref must be corrected by adding [\* Reference].

# Replace the [Pin Reference] BIRD With the DUT\_ref\_term BIRD

- DUT\_ref\_term is a new subparameter in the [Model] section that specifies which rail terminal of the buffer was used as the reference terminal in Device Under Test.

# DUT\_ref\_term BIRD

*Subparameter:* DUT\_ref\_term

*Required:* No

*Description:* This subparameter defines for this [Model] the rail terminal that should be used for measuring the voltage at all terminals of the model.

*Usage Rules:* The simulation node at the reference\_terminal should be used as the reference node of measurements at the pin\_name node and all rail nodes when comparing simulation results with model thresholds. The only allowed values of reference\_terminal are Pulldown\_ref, Gnd\_clamp\_ref, Pullup\_ref and Power\_clamp\_ref.

*Other Notes:* If the reference terminal's corresponding DUT test condition voltage ([\* Reference]):

[Pulldown Reference]

[GND Clamp Reference]

[Pullup Reference]

[POWER Clamp Reference]

Is not 0.0, then the EDA tool should add the value of ([\* Reference]) to the voltage at all of the nodes measure referencing the DUT Reference Terminal.

If a [Model] does not have a [DUT Reference Terminal] then:

If the model type is not ECL, the EDA Tool should use a rail terminal that has a [\* Reference] value that is 0.0V.

If the model type is ECL, then the EDA tool should use the terminal that has the maximum [\* Reference]

If a [Model] does not have a [DUT Reference Terminal] and there is no rail terminal that has a [\* Reference] value that is 0.0V, and the model type is not ECL, then the EDA tool should use the Pulldown\_ref terminal if it exists, otherwise the EDA tool should use the GND\_clamp\_ref terminal.

# But What if Some Thresholds are Sensitive to the Power Rail?

- This is an important but totally separate issue.
- If the voltage difference between the Power and GND rails in a DIA is different than the this difference in a DUT, then, in general, IBIS does not tell you how to adjust the thresholds defined in the model. We are now calling this “scaling”, which has been implemented for limited thresholds in [Receiver Thresholds]
- Any “scaling” intelligence based on technology can be defined and applied, but this is totally independent of what voltage measurements need to be made at an I/O buffer. These measurements must be between the terminals of the buffer.

# What About Pin vs Buffer Measurements

- IBIS specifically allows measurement rules to be applied at the buffer terminal (pad) or the pin.
- Since the electrical distance between the pad and pin can be  $\sim 100\text{ps}$ , then the measurement of all buffer terminals should be made either between pad terminals or pin terminals.
- Note that various standards require measurements at the pin. These measurements are made for compliance tests, not necessarily to predict the actual timing performance of the device.