High Frequency PWB Design Verification using In-board TDR Measurements

Important Process Questions/Answers

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The following is a list of typical questions and answers associated with the process of utilizing in-board (image area) TDR measurements for PWB Design Verification. The following questions are addressed:

1) What high frequency information can be provided by the process?
2) What are the specifications of the test equipment?
3) What data is needed to setup and define the test process?
4) What are the geometries on the board that are required to allow TDR probing?

What high frequency information can be provided by the process?

The following is a list of high frequency data that is available:

Raw Data Available from Automated TDR Data Collection

1) Interconnect impedance on single-ended and differential structures (also assembled connectors, daughter cards, etc.).
2) Interconnect signal flight time (propagation delay, Effective Er)
3) Interconnect Bandwidth (interconnect insertion loss)
4) Impedance, delay, bandwidth on both sides of differential pair
5) Signal profile (TDR Waveform) for via characterization, etc.

Information and Analysis Available on New Designs

1) Impedance of critical PWB interconnects
2) Bandwidth (insertion loss) for all critical nets
3) Average Impedance by board layer
4) Impedance variance across the board
5) Maximum high speed bus skew
6) Flight time on critical nets
7) Average propagation delay per layer
8) Average propagation delay variance across the board
9) Affects of vias and stubs on impedance and delay
10) Affects of close trace spacing on impedance and delay
11) Differential trace impedance
12) Differential trace pair skew due to routing differences

13) Variance between image area board impedance and “TDR coupon” trace impedance

Benefits of Information

1) Fine tuning of passive models
2) Verification of PWB design impedance and propagation delay
3) Understanding of PWB vendor capability
4) Understanding of PWB material variance thru Effective Er data
5) Ability to calibrate product’s critical interconnects
6) Automation of measurement system brings confidence in data collected

What are the specifications of the test equipment?

The following is a list of the primary test system specifications:

1) Impedance
   a) Absolute values – Estimated at +/-0.2 ohms
   b) Repeatability – 0.05 ohms
2) Interconnect Signal Flight Time
   a) Absolute values – 1 psec + 1% of time interval
   b) Repeatability – 4 psec
3) Test System Risetime (Incident pulse) : 25 psec (Approx. equivalent test bandwidth of 14 GHz)
4) Test Speed: 800-2000 data points per hour

What data is needed to setup and define the test process?

The following is a list of the required information necessary to define and build a test file for in-board high frequency probing:

1) Gerber (274X preferred) or Allegro File
2) IPC-D-356 Net List (includes actual Signal/Net Names, Node Names, XY location of all nodes including all references power/grounds, via or hole, hole size, side access, presence of soldermask)
3) List of all nets which are required to be tested (identified by Signal/Net Name). Note that differential pairs should be listed together.
4) Physical trace length (inches) for each trace {Optional} Reduces test time if propagation delay is not required. Alternately the availability of trace length provides prop velocity and Effective Er calculated values if propagation delay is measured.
5) Definition of region of interest within each interconnect for impedance related measurements. {Defined as a starting percentage and ending percentage of trace length} This is required to allow the establishment of “measurement zones” within each trace being measured– assists in the elimination of trace elements which may not be of interest (i.e., launch, termination or midpoint vias).

Introbotics test generation software and process will utilize the list of desired nets to test and extract the appropriate testable nodes and find geometrically close reference node(s) (ground/power pin) from the IPC netlist. Gerber is utilized to establish reference fiducials for the systems camera and for manual cross checking of the test program.

What are the geometries on the board that are required to allow TDR probing?

Board pad/via requirements for single-ended TDR testing

1) Signal pad/via to reference (ground or power) pad/via spacing: Range: 40mils -to- 100mils (full range between these two values)

2) Signal or reference via finished hole size: 30mils or smaller (Note: Larger holes may cause the TDR probe pins to "float" inside the hole and not make proper electrical contact to make a measurement)

3) Signal or reference pads/vias should be a minimum of 0.100" from the edges of the board

4) Pads/vias not covered with soldermask

5) Interconnects must be at least 0.5 inches long.

6) Pads/vias should be considered as endpoints of a net

7) Interconnects with midpoint vias or branches can be tested as long as the location of the impedance measurement zone is defined to either included or exclude these features of a net.

8) Pads/vias locations should include reference to top or bottom side probing.

Board pad/via requirements for differential TDR testing

1) Differential probes are a little different from the single-ended TDR probes. There can be upto 4 probe tips on each probe and those tips can form all types of patterns (i.e., squares, rectangles, line, L-shape). There is a potential for a large variety of probes required to test any one board. We have some probes already made up and we can make almost any shape and size but there can be upto a 6 week lead time in the fabrication of custom probe patterns.

2) We currently have in-house the following differential probes:
Signal to Reference Pitch: 100mil Signal -to- Signal Distance: 100mil Ground -to- Ground Distance: 100mil (i.e., 100mil Square)
Signal to Reference Pitch: 88mil Signal -to- Signal Distance: 88mil Ground -to- Ground Distance: 88mil (i.e., 88mil Square)

Signal to Reference Pitch: 70mil Signal -to- Signal Distance: 70mil Ground -to- Ground Distance: 70mil (i.e., 70mil Square)
Signal to Reference Pitch: 40mil Signal -to- Signal Distance: 40mil Ground -to- Ground Distance: 40mil (i.e., 40mil Square)

3) With the above mentioned probes we do have the relatively simple capability of moving around the ground pins to produce different Signal to Reference Pitches and Ground-to-Ground distances but the Signal-Signal Distances are not changeable for a given probe.

4) Differential TDR measurements can be taken WITHOUT using reference pads/vias (the two signals traces reference each other only and not the ground/power planes). It is preferred to have at least one ground/power pin available when taking differential TDR measurements.