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Backdrilling Technology for Backpanel

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Abstract

In order to get excellent signal Integrity, half PTH holes will be a new trend in high frequency backpanel designing. Backdrilling is necessary for this application. This paper explores the application range, technology tickler, technology method and reliability testing of backdrilling for backpanels.

Key words: backdrilling; signal integrity; thermal stress; counter bore

Preface

As the signal frequency is higher and higher, the PCB becomes one of the important factors that affect signal integrity. Figure 1 shows the backpanel system. According to research, the PCB material, transmission trace, connector, chip packaging and PTH hole are the main factors that affect signal integrity.

In the backpanel some signal is transmitted from layer 2 to layer 4 through a PTH. If the backpanel is 20 layers, except the part from layer 1 to layer 4, the other part oft he hole is unused. This portion, even though unused for signal transmission affects signal integrity. The hole wall and the pad can become a capacitor just as a pad and pad a become a capacitor, they will therefore interact and disturb each other. For backpanels because the thickness is higher and the hole length longer the stub-length has more effect on signal integrity than a PCB of normal thickness. The maximum line length permitted is thus badly affected.

Backdrilling is the technology that can solve the problem of stub-length. Below is a discussion and presentation on backdrilling technology. (See Figure 2.)

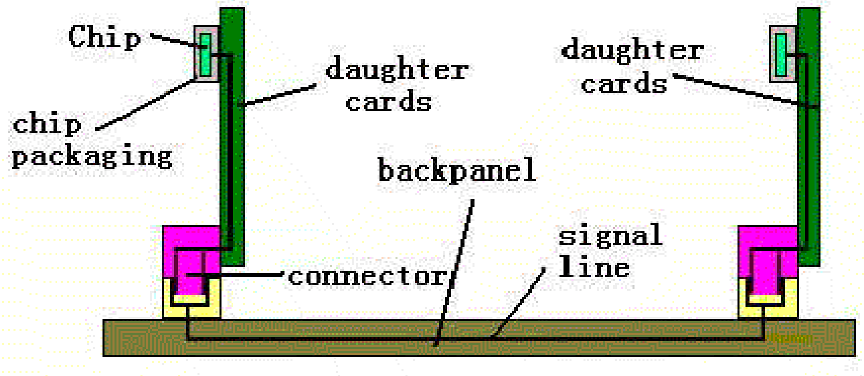

Figure 1 – Backpanel System

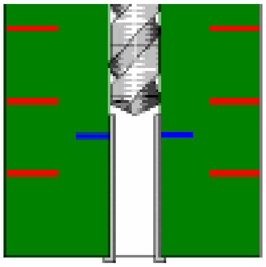

Figure 2 - Backdrilling

Why We Need Backdrilling?

Capacitance Specialty of PTH

For discussion, stub length will designated as Ls. Ls has an affect on capacitance, and, at the same time, can interact with signal lines and the pads of other signal pad just as a pad to pad interaction or a hole wall to pad interaction acts as a capacitance. Any of these will affect signal integrity.

Stublength Influence the Maximum Length of Signal Line

Researches suggest that on certain condition stub length has little effect on the maximum signal line length at 2.5 GHz. But that is not the case for 10 GHz, at which layout is impossible if Ls is greater than 3.2 mm, even if the strength of signals is pre-enhanced by 200%. Therefore, at high frequency, the Ls is one of the important factors which influence maximum signal line length.

Influence of Ls on Impedance Matching

We have measured the impedance of the models (assembled with the plugs) based on different stub lengths Ls, realized by backdrilling technology. The results show that the effect on impedance matching may decrease as Ls decreases.

Effect of Ls to Signal Loss

Figure 3 plots the relation of the crosstalk vs. the unused hole length (Ld) which we get by backdrilling .The thickness of backpanel is 4.64mm. The source voltage is 1V and rise time is 35ps. Through the test, we found that the crosstalk decreases with the increasing of Ld. The verdict: the shorter the Ls is, the less the crosstalk is.

Figure 4 shows the insertion loss vs. Ls at some frequencies. It can be seen that the insertion loss is less for shorter Ls. Also, higher the frequency is, the higher the loss becomes.

From these experiments, we know that Ls has important effect on signal loss. The longer Ls is, the greater the loss is.

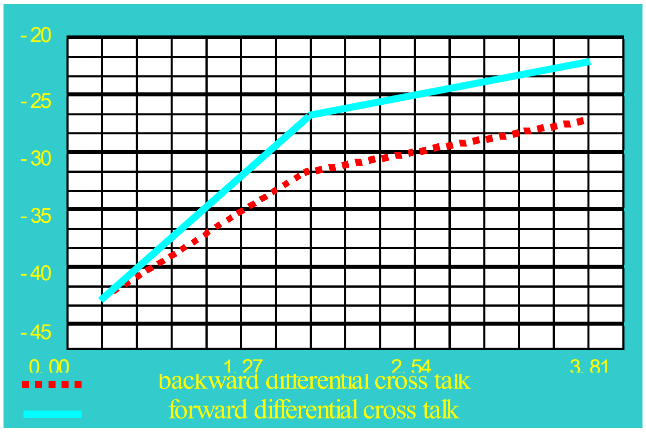

Figure 3 - Ls Vs. crosstalk

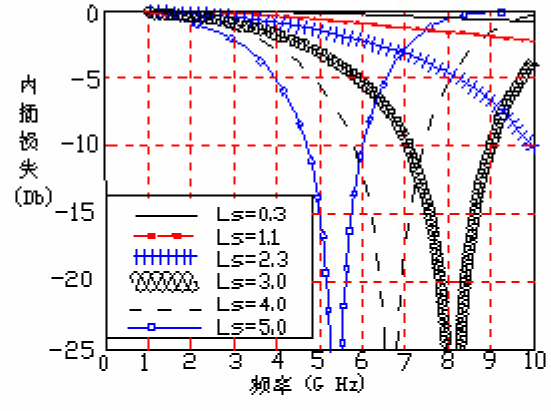

Figure 4 - Ls（mm）Vs Insert Lose

Backdrilling is the Best Method that can Solve Problem of Ls

From analysis above, we know that Ls can have a bad effect on system signal integrity at high frequencies. When we remove the unused portion of the signal hole by backdrilling, the transmission performance of the board at high frequencies can be greatly improved. HDI/BUM and buried blind hole technology can also solve these problems but result in higher cost, longer processing period and higher reject ratio. At the same time, these two technologies cannot adapt to backpanels that mainly uses press fit connectors. Therefore, backdrilling is the best method to solve Ls problems and we must develop it.

Realization of Backdrilling

In Figure 2 one can see that backdrilling is a technology that drills the unused portion of the signal hole using a drill who's diameter is only a little bigger than the diameter of the plated through hole.

In fact, our customer purposes that the diameter difference of the two drills should be as small as we can do. Thus accuracy of hole drilling is a strict requirement. If the accuracy is bad, one side of the copper on unused portion of the hole wall may not be drilled/removed affecting reliability and signal integrity.

At the same time, our customer purposes controlling the depth on the two layers with the dielectric thickness between the two layers presumed to be 0.10mm.If depth is too shallow, it will affect SI, otherwise, the signal line on the next layer will be damaged.

Difficulty of Backdrilling Technology

The Situation Accuracy of the Secondary Drill

Technical requirement - The difference of diameter between counterbore and through hole is smaller than 0.2mm, i.e. the whole tolerance of inner layer's contraposition and hole situation must **below ±0.10mm**.

Analyze - If the diameter of anti-pad of the counterbore is augmented 0.08mm and the contraposition accuracy of inner layer is ±0.075mm, the repeated accuracy of the first drill and the secondary drill should be ±0.065mm. So, the hole position error of two time's drilling should below 0.04mm. It tells us that accuracy of orientation, contraposition of inner layer and accuracy of drill is *highly required* by backdrilling.

Thickness Consistency of Backpanel and Depth Control of Backdrilling

Technical requirement - The depth of secondary drilling must end between the two layers where the dielectric thickness between the two layers will be at least 0.10mm.

Analyze - In order to fulfill these requirements, we must emphasize control over the accuracy of depth in counterbore drilling and the consistency of backpanel's thickness.

Control the Burry, Roughness and the Integrality of the Hole Profile in the Secondary Drilling

The emphasis on reliability at the bottom of the counterbore is depends on backdrilling control. The secondary drill may damage the PTH copper at the bottom of the conterbore. It may produce burrs or even rip the PTH copper. Backdrilling must not impair the binding strength of the hole wall with the plated copper. Also, the hole profile at the bottom of the counterbore must be controlled.

Method of the Backdrilling

According to analysis, we know that the primary parameters to emphasize in backdrilling are to control of the contraposition accuracy of inner layer, thickness consistency of backpanel, depth control accuracy in secondary drilling, and the position error of drilling.

The method of depth control:

- *Capability of depth control in backdrillin*g - The drill machine should be selected as the one who's depth control accuracy is ±0.015mm. According to the pin of the connector, we selected the diameter of through holes as follows:

  0.6mm,0.7mm,0.8mm,0.9mm.

  The diameter combination of the through hole and counterbore is expressed in Table 1.And then we confirm the capability of depth control.

- *Selection of technology process* - The emphasis is how to select a process that can drill the counterbore with high accuracy of depth control. We can drill the counterbore after solder mask, trim pattern, plating or before routing. And then authenticate the depth control capability of each process.
- *Thickness control of backpanel* - We should control the thickness of laminate and quality of prepreg, change the shape and distribution of baffle pad calculate the backpanel thickness accurately and adjust the parameter of laminating.

Table 1-Combination of Diameter

Diameter TH (mm)	Diameter of counter boring （ mm ）	Diameter TH (mm)	Diameter of counter boring （ mm ）
0.6	0.75,0.80,0.85,0.90,1.00	0.8	0.95,1.00,1.05,1.10,1.20
0.7	0.85,0.90,0.95, 1.00,1.10	0.9	1.05,1.10,1.15,1.20,1.30

After these experiments were completed, three types of sample were produced, each with a layer count of 20.The dielectric thickness of these samples is divided to 0.1mm, 0.2mm, 0.25mm. Through these experiments, we can confirm the capability of thickness control.

Control of position tolerance:
- Displacement of Drill machine should be controlled by linear motors, the position accuracy setting is 0.01mm, adjusted by the verticality of table and drilling head. The accuracy of depth control should be 0.015mm.
- The contraposition accuracy of inner layer should be controlled to ±0.075mm.
- The drill should have high rigidity, less helix angle and a big point angle. We selected a short slot drill.
- Improving the orientation system of the drill changes the parameters of the drill.

Vision and reliability at the bottom of counterbore:
- Evaluate the quality of counterbore and vision at the bottom of counterbore by combination experiment of parameter.
- In order to find out the relation between the copper thickness of hole and reliability at the bottom of counterbore, the copper thickness of the hole was varied as 5um, 15um, 25um, and 35um in the experiment.
- Affirm the vision and reliability by drilling counterbore after filling special material.

Experiment results

Depth Control

Process select - The experiment shows that there is little difference between drilling after PTH and after etching for the accuracy of depth control. But the accuracy of both processes is better than other process. So, we can drill counter bore after PTH or after etching per the technical requirement.

Depth control - The experiment indicates that the depth accuracy has little relation to drill diameter when the diameter is bigger than 0.5mm.The accuracy of depth that we can control is 0.04mm when CPK is 1.33. This accuracy is noted as ≥1.

Table 2 shows the tolerance of whole thickness we can control when CPK is 1.33. If we note the tolerance as ≥2, our backdrilling's depth control capability of 20 layers backpanel is:

≥1+（depth of countebore/whole thickness）×≥2

It relate to material, layer structure and depth of counterbore. The depth control capability of other layer structure can be calculated by this data.

Table 2 - Thickness Tolerance of Whole Thickness

parameter series No.	Layer	Dielectric thickness	Tolerance of whole thickness (≥2)
A	20	0.1mm	±0.07mm
B	20	0.20mm	±0.09mm
C	20	0.25mm	±0.12mm

Position Accuracy Experiment
When CPK is 1.33, the coaxiality accuracy of counterbore and through hole is 0.042mm.

When the orientation of inner layer is 0.075mm, the situation accuracy of counterbore is ±0.117mm. So, when the diameter of counterbore is 0.2mm bigger than that of through hole, we require the minimum diameter of anti-pad to be 0.24mm bigger than diameter of counterbore.

Control of Burr, Roughness and Integrality of the Hole Contour at the Bottom of Counterbore
The experiment indicates that the secondary drilling is very difficult, if it contacts the material and thickness of hole copper. The thinner the hole copper is, the harder it is to be drilled. The more flexible the material is, the harder it to be drilled. But, we can get excellent quality by adjusting the parameters of drill or filling with special material:

roughness≤25um, burr is accepted and the hole contour is integral and smooth even after 5 times thermal stress.

Reliability and Test of Backdrilling

There are no special IPC criterion on reliability of backdrilling, so, based on our testing of backpanels, we must develop new test items based on the characteristics of backdrilling.

Because of the stub in the hole, the reliability is weakened. Specially then, we must review the presence of burrs, the integrity of the hole contour, the binding strength of hole wall with hole copper and the distance from bottom of counterbore to the next signal layer. Also, environmental testing is necessary.

If the connector is press fit connector, the environmental testing should be done after pressfit pin header testing or testing of the pull-out strength of hole.

So, the test items backdrilling requires are as follows:

Thermal stress, environment test, pull-out strength, distance from bottom of counter boring to the next signal layer, vision at bottom of counterbore. (See Figures 5 and 6.)

5 - Microsection without Thermal Stress

Figure 6 - Micro Section with Five Times Thermal Stress

Question that Backdrilling Brought

Research shows that there will be a minimum of 1000 backdrilled holes for every 40000 PTH holes. Recently, we have four backpanel parts that have 3800 backdrilling holes in 20000 holes.

Tolerance of the laminate, incoming material quality consistency of different lots and presser capability affect the thickness of backpanel. Thinner inner layers are the trend of backpanels. So, capability of depth control will be greatly challenged. There is no automatic online test equipment for the depth of counter boring. Thus , an electric test method must be developed.

Conclusion

In high frequency systems, the unused portion of signal PTH is one of the important factors that affect SI of system. It affects the max. length of signal line and impedance matching. It can product signal crosstalk too.

Backdrilling is the best technology that can solve the problem of unwanted Ls. We have developed backdrilling technology and have mass-produced backpanels using it. But, as with most of our craft brothers, the PCB dielectric thickness which can be mass-produced is thicker than 0.20mm. This si still not a match for our customer’s requirement. Thus our study will go on.

Reference

1. Jan De Geest, Jim Nadolny, Stefaan Sercu “How to make optimal use of signal conditioning in 40 Gb/s copper interconnects,” FCI Communications, Data, Consumer Division, DesignCon 2003
2. Dr James Clink “Maximizing 10Gbps Transmission Path Length in Copper Backpanels with and without Transceiver Technology,” DesignCon 2003
3. Tom Cohen, “Practical Guidelines for the implementation of back drilling plated through holes vias in multi-gigabit board applications,” DesignCon 2003
4. Teradyne, Inc. “Signal Integrity Characterization of Printed Circuit Board Parameters,” DesignCon 1999

Discuss of Back-drilling Technology for BackPanel

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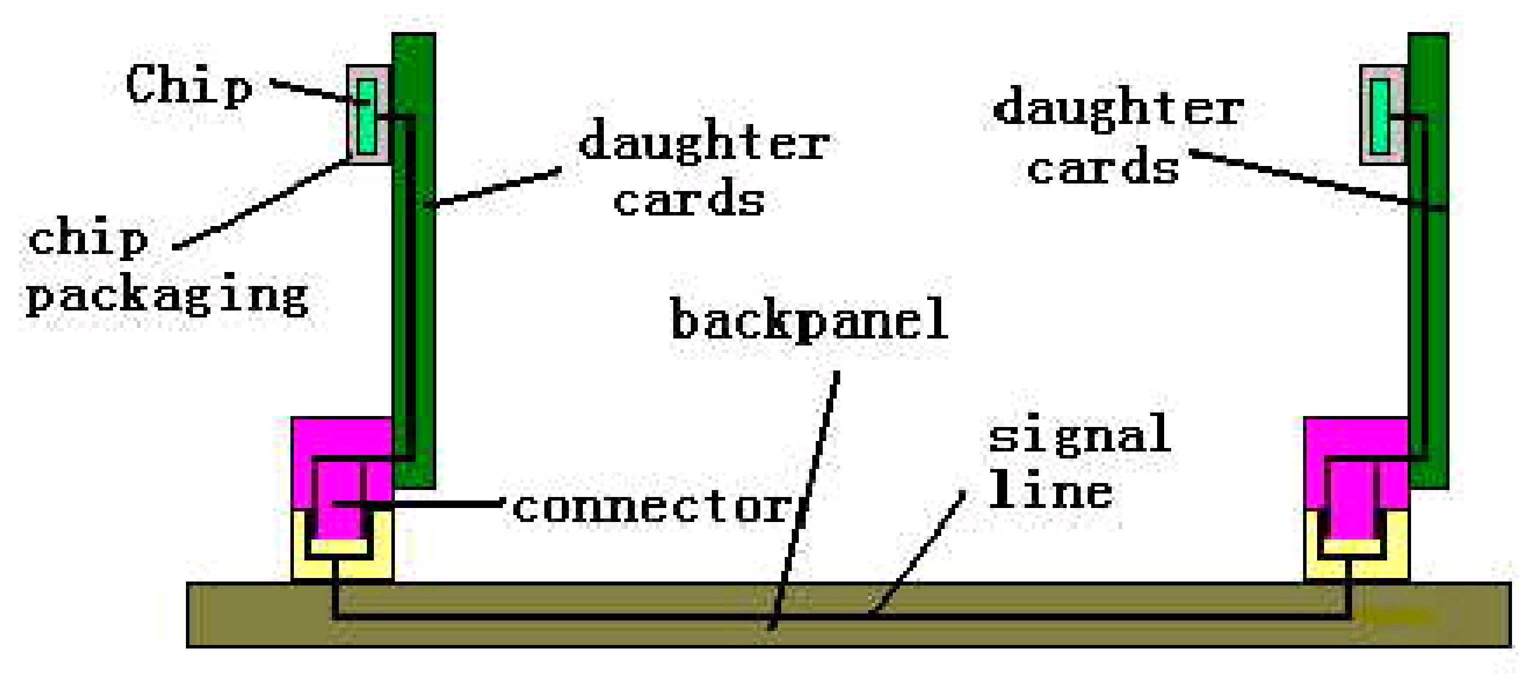
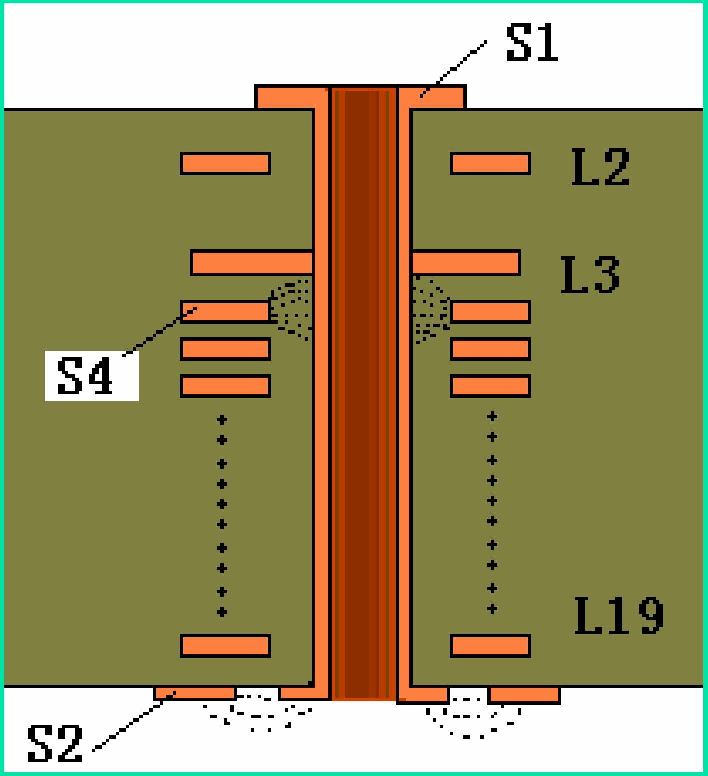
Signal System of Backpanel



Envirement Factors Which Affect SI of Backpanel

- Design
- Material of PCB
- Signal Line
- PTH
- Connector
- Chip packaging

The Signal Via. Affect SI

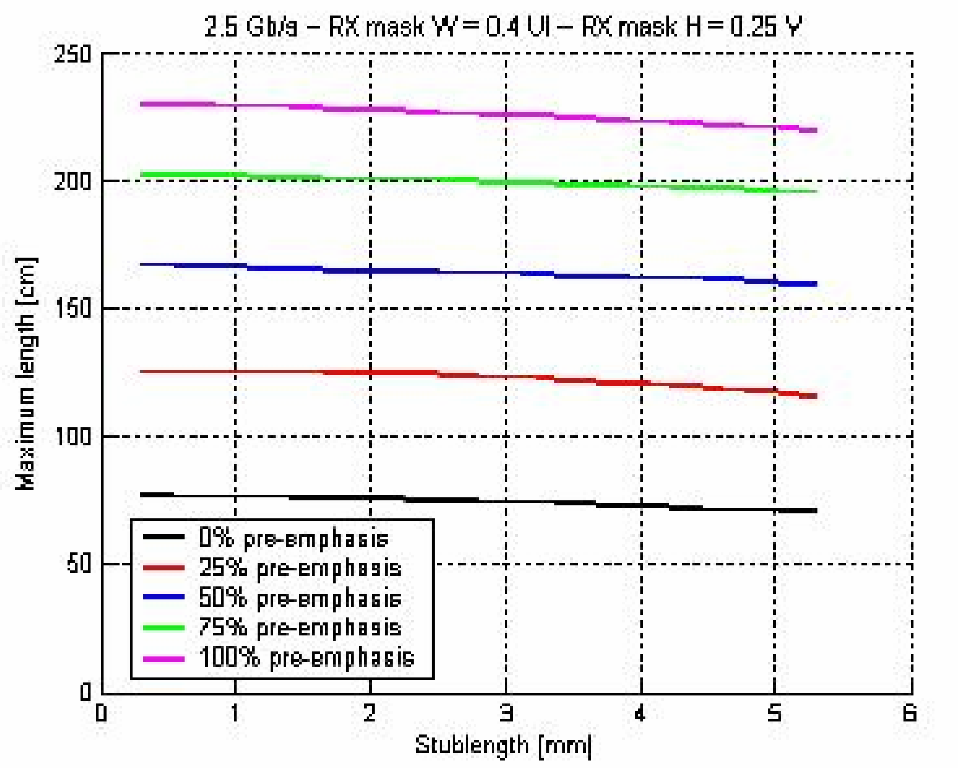


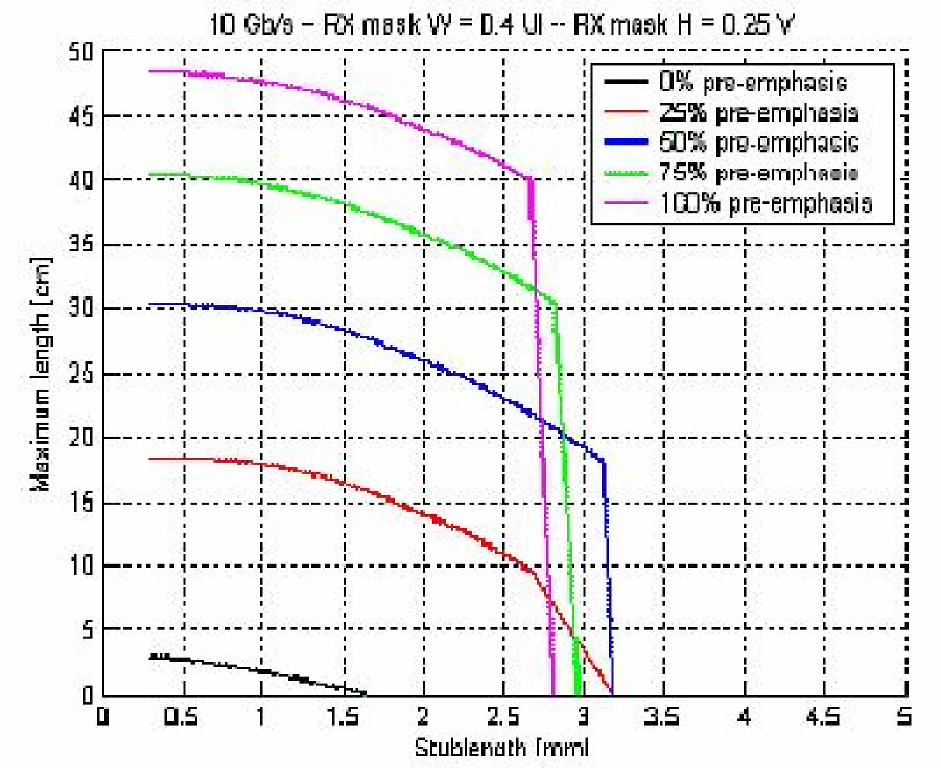
- Some signal may transmit from layer1 to layer 1.The part from layer 3 to layer20 is unwanted.The unwanted part may become capatance with other signal conductor.
  - S1-S4
  - S1-S2

Capacitance Characteristic of PTH hole

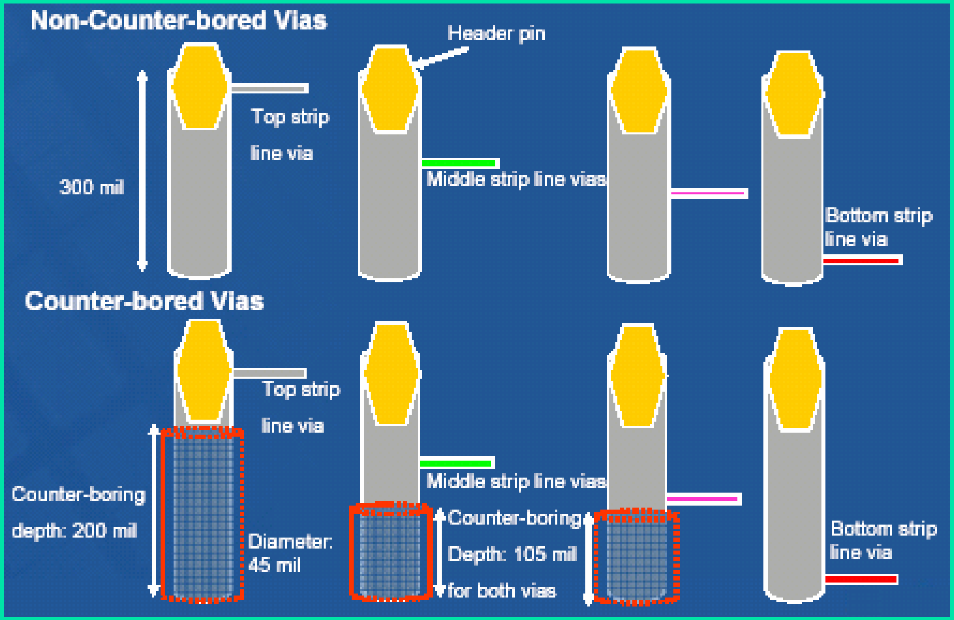
Dia. Of drill（mil）	Dia. Of PTH（mil）	Dia. Of anti-pad（mil）	Dia. Of pad (mil)	Length of PTH hole (mil)	Equivalent capacitance（pf）
26	22	52	38	250	2.4
26	22	52	38	200	2.0
26	22	52	38	225	1.8
26	22	52	38	150	1.5
26	22	52	38	125	1.3
26	22	52	38	100	1.0

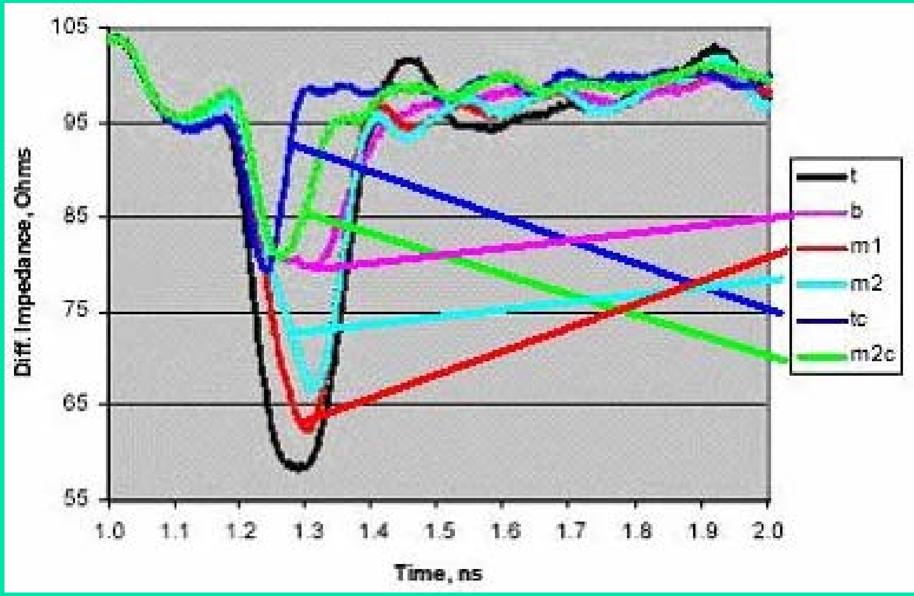
Ls Vs Max Trace line



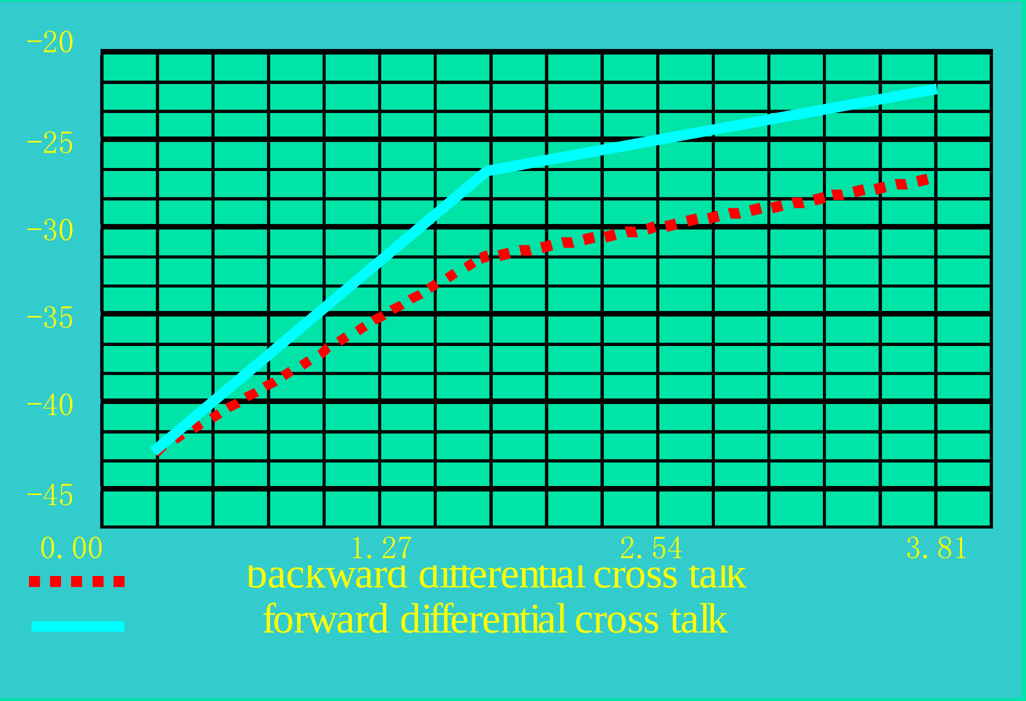


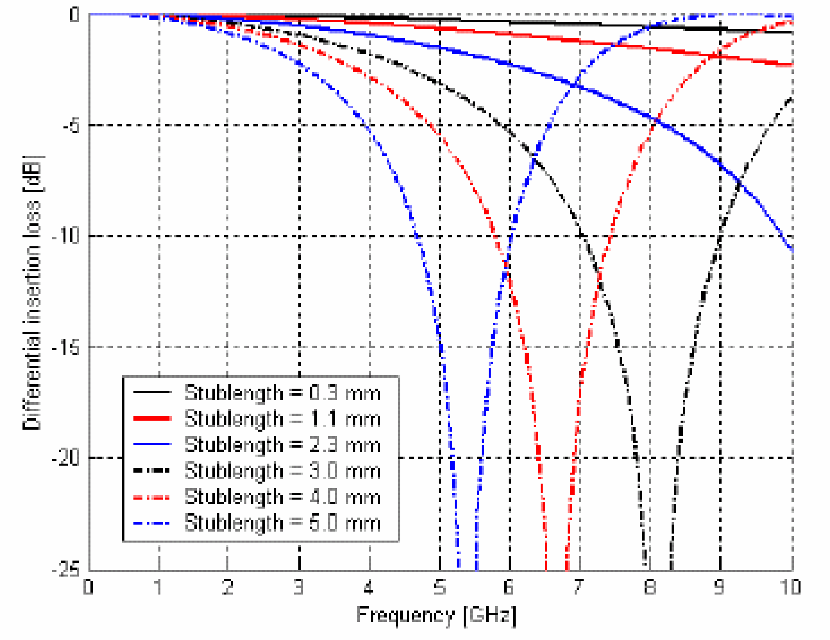
Ls Vs. impedance matching





Ls Vs. Loss





Ls(mm) Vs. crosstalk

Ls（mm）Vs. insertion Loss

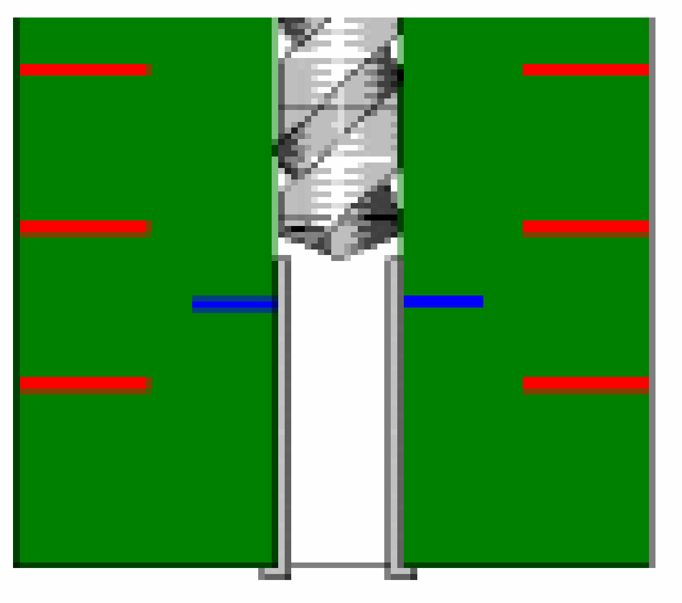
Buried blind hole and HDI

- Buried blind hole:
  - Can solve the problem
  - Cost is increased greatly
  - Not adapt to press fit connector
- HDI:
  - Can solve the problem
  - Cost is increased greatly
  - Not adapt to press fit connector,Diameter of hole is limited.

Back-drilling—
The best technology for Ls

- Can solve the problem of Ls
- Cost increase little
- Adapt to press fit connector

Technology of Back-drilling



Back-drilling:

back-drilling is the technology that drill the unwanted part of the PTH hole by the drill which diameter is little bigger tan diameter of through hole.

Difficulty of Back-drilling

- **The position accuracy of the second drill**
- **Thickness consistency of backplane and depth control of back-drilling**
- **Control the burry, roughness and the integrality of the hole profile in the second drilling**

Combination of Diameter

Dia. of through hole (mm)	Dia. Of counterbore （mm）
0.6	0.75,0.80,0.85,0.90,1.00
0.7	0.85,0.90,0.95, 1.00,1.10
0.8	0.95,1.00,1.05,1.10,1.20
0.9	1.05,1.10,1.15,1.20,1.30

Depth Control

- Drill Machine
  - **Selection of drill machine**

    Select drill machine which can control depth by surface of backpanel
  - **Depth control capability of drill machine**

    0.015mm

Depth Control

- **Selection of technology process**
  - second drill after PTH
  - Second drill after trim pattern
  - Second drill after solder mask
  - Second drill after route

Depth Control

- Thickness control of backpanel
  - Control the thickness of laminate and quality of prepreg
  - Change the the shape and distribution of baffle pad
  - Adjust the laminate parameter
  - Certificate the capability of thickness control by experiments.The dielctric thickness of the three 20-layer sample is divided to 0.1mm， 0.2mm and 0.25mm.

Control of Position tolerance

- Control position tolerance of drillmachine
  - the situation accuracy setting is 0.01mm
  - adjust the verticality of table and drilling head
- The drill should has high rigidity,less helix angle and big point angle
- Improve the contraposition system
- The contraposition accuracy of inner layer should be controlled in ±0.075mm

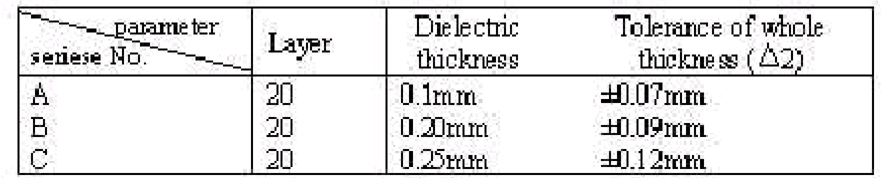
- **Vision and reliablity at the bottom of counterbore**
  - Evaluate the quality of counterbore and vision at the bottom of counterbore by combination experiment of parameter.
  - Find out the relation betwee the coper thickness of hole and reliability at the bottom of counterbore by different hole copper thickness

Postion Tolerance Control

- Process selection:Drill after PTH or trim pattern
- Coaxiality accuracy of counterbore and through hole is 0.042mm（CPk=1.33）.
- When the orientation of inner layer is 0.075mm,the situation accuracy of counterbore is ±0.117mm.So,when diameter of counterbore is 0.2mm bigger than that of through hole,the minimum diameter of anti-pad is 0.24mm bigger than diameter of counterbore.

Capability of Depth Control

- Depth accuracy has little relation to drill diameter when the diameter is bigger than 0.5mm
- The accuracy of depth that we can control is 0.04mm(Cpk=1.33)
- The whole thickness of 20-layer backpanel that we can controlled(Cpk is 1.33):



parameter seriese No.	Layer	Dielectric thickness	Tolerance of whole thickness (△2)
A	20	0.1mm	±0.07mm
B	20	0.20mm	±0.09mm
C	20	0.25mm	±0.12mm

- What capability we can do is:

△1+（depth of counter boring/whole thickness）×△2 。

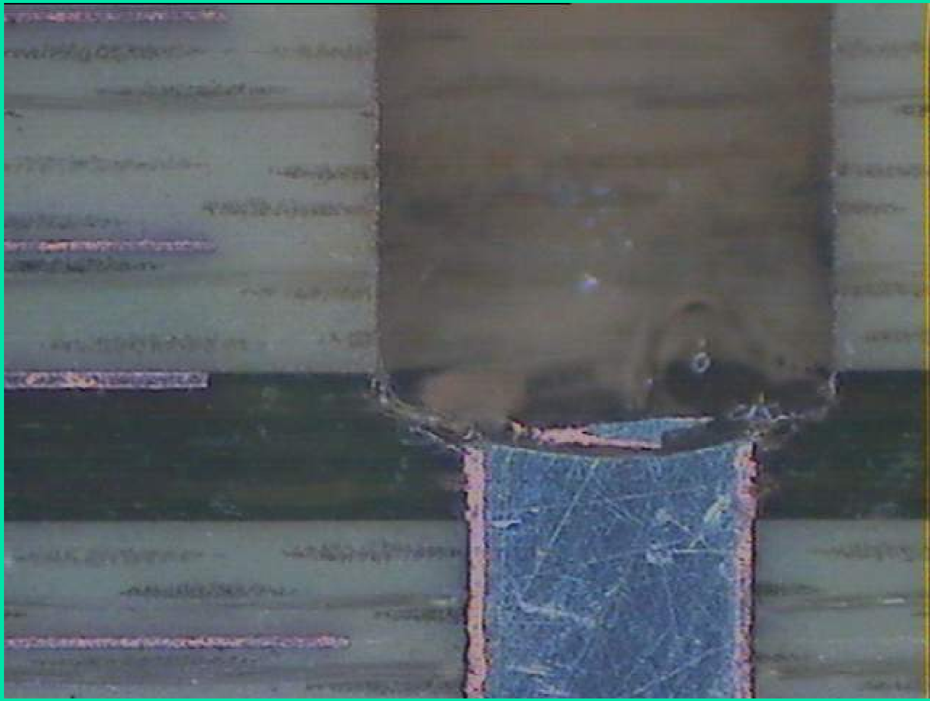
- The depth control capability of other layer structure can be calculated by this data.

Burr ,roughness and integrality of the hole contour at the bottom of counterbore

- Thinner the hole coper is,more hard it to be drilled
- More flex the material is,more hard it to be drilled
- roughness≤25um
- burr is accept and the hole contour is integral and smooth even after 5 times thermal stress.

Reliability and test of back-drilling

microsection without thermal stress



microsectionwith five times thermal stress

Test item which back-drilling should added:

- Thermal stress
- enviroment test
- pull-out strength
- distance from bottom of counter boring to the nex signal layer
- vision at bottom of counter boring

切片 without thermal stress

切片with five times thermal stress

Question that back-drilling brought

- Thinner inner layer is the trend of backplane
- No automatic online test equipment for the depth of counter boring
- Tolerance of laminate ,incoming material quality consistency of different lots
- presser capability

Conclusion

- In high frequency system,unwanted part of signal PTH affect SI
- Back-drilling is the best’technology that can solve the problem of Ls
- We developed back-drilling technology and have mass-produced
- we still can’t match our customer’s final requirement,our study will go on

Thanks

- 1.Jan De Geest,Jim Nadolny,Stefaan Sercu " How to make optimal use of signal conditioning in 40 Gb/s copper interconnects"FCICommunications, Data, Consumer Division, DesignCon 2003
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