The benefits of v-scoring

Since you are a very busy engineer, operator or manager involved in many other important areas, we offer this concise review of the fundamentals of v-scoring, that will produce the accurate and functional product that you desire.

The benefits of v-scoring are well documented. The efficiencies gained in producing multiple assemblies from a single manufacturing cycle, ensure the continued success of this value added process. There are also several cost saving benefits to be realized by the PCB manufacturer who takes just a little bit of time to learn the basics of this versatile process.

V-Scoring, not unlike most fairly new processes, is not always an instant consideration in manufacturing design. So we will highlight some of the areas that can be most challenging to discover through experience.

How Deep?

This is unquestionably the most frequently asked question in the scoring business.
Choosing a depth that will provide a sturdy work-piece and still separate with light to moderate pressure after assembly, is an important element in profitable manufacturing.

Specifications:

Most score depth specifications make use of one of the following conventions:

1. V-depth measured from one or both sides of the PCB surface. Or, the more appropriate...
2. Cross-sectional view, indicating the distance between Vees. This residual material is called the **Web**.

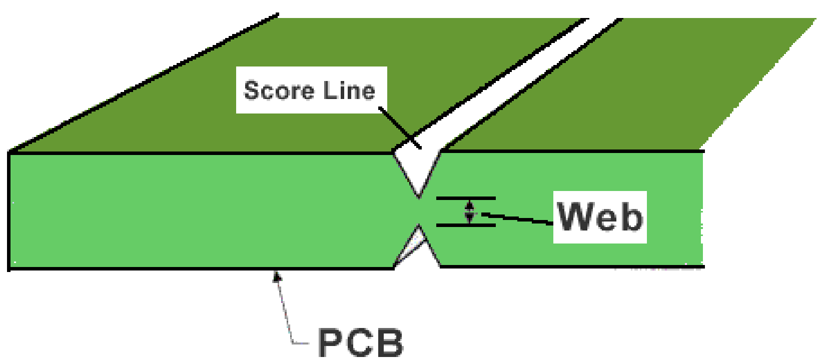


Figure 1. Cross-sectional view, indicating the distance between Vees.

Optimum Web Thickness.

Determining the thickness of this uniform core of material for each individual project is really very simple.
We need only consider the needs of the subsequent assembly operations. In the assembly area we are looking for the following performance criteria:

1. Overall part planarity, not only for component placement, but also for solder reflow and/or wave processes.
2. Ease of de-paneling. After component attachment is complete, the individual boards should break apart with only moderate pressure.

Web Thickness Guidelines

General Web Thickness Guidelines For Panel Scoring .062" (1.6 mm) Thick FR-4

Individual	< .5"	.5" to 1.0"	1.0" to 3.0"	3.0" to 6.0"	> 6.0"

PCB					
< 5"	.005"	.007"	.009"	.010"	N/A
5" to 10"	.006"	.008"	.010"	.012"	.012"
10" to 15"	.007"	.009"	.010"	.012"	.013"
15" to 20"	.005" (break only)	.009"	.011"	.013"	.015"
> 20"	.005" (break only)	.005" (break only)	.012"	.014"	.015"

Note:
These are GENERAL guidelines. The final decision on web thickness should be made only after careful consideration of future process and handling requirements... **THIS GUIDE IS FOR REFERENCE ONLY!** *+/-0.002" is standard tolerance.*
For more information on depaneling without damaging the board or components, see references to Jump-Scoring in the section below for more advanced details on web thickness vs. producability.

Notice how the web gets thinner as the individual board size gets smaller. The smaller the part, the less leverage that you can apply to the score line.

One of the great features of most modern CNC scoring equipment, is the ability to easily program the web thickness from line to line and axis to axis.
One popular application for this feature of varying web thickness is called **"Deep Cut"** or **Framing**. This is where the outside border of the array is cut to a relatively thin web of down to .006". This allows for an easy break off of the scrap frame.
This is also commonly used to easily separate multiple arrays from a production panel, without the worry of breaking the wrong line.

How Wide?

Actually, almost no one asks this question... but they should.
Understanding the variables that determine score width along with the associated process tolerances, will help you identify problematic specifications, and aid greatly in laying out a manufacturable product.
Knowing what your score width will be is essential to design and planning. Understanding the variables that determine score line width is, once again, quite straightforward.

Variables.

Score line width is determined by a combination of two elements; blade angle and blade wear. Simply stated, a blade of a larger angle will cut a wider path than a blade of a narrower angle, at the same depth. Also, the deeper the blade penetrates the surface of the board, the wider the path will be. Also, as the blade wears, the tip essentially "moves up" the width of the blade, resulting in a wider score path for the same given web. **Note Figure 2...**

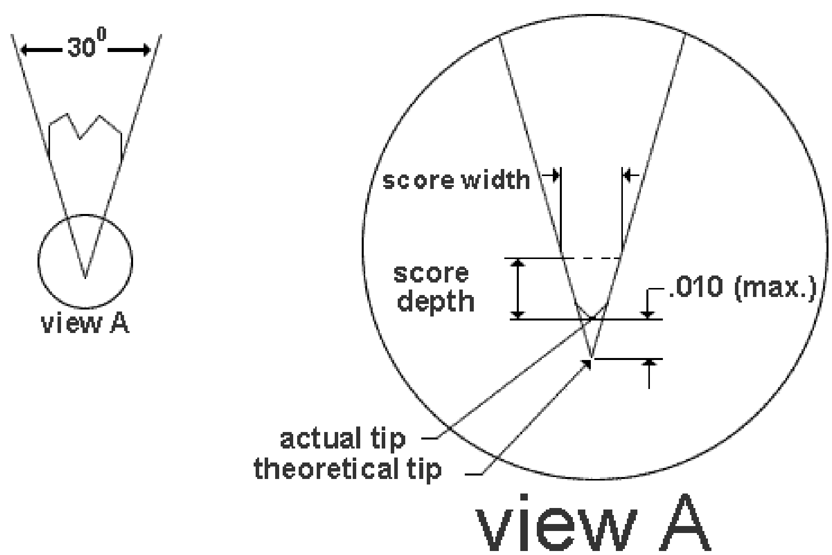


Figure 2. Score line width is determined by a combination of two elements.

Score Depth	**Score Width (at 'zero' tip wear) (30°blades)**	**Score Width (at MAX. tip wear) (30°blades)**
.010"	.005"	.013"
.012"	.006"	.015"

.014"	.008"	.016"
.016"	.009"	.017"
.018"	.010"	.018"
.020"	.011"	.019"
.022"	.012"	.020"
.024"	.013"	.021"
.026"	.014"	.022"
.028"	.015"	.023"
.030"	.016"	.024"

As you can see, there is a little more to score width than meets the eye.
For the sake of simplicity and real world conditions, we can be **safe** in saying that, a 30 degree blade, throughout its service life, will require a surface clearance of .020" +/-.004". To this number we can add equipment tolerances at +/-.002" and you fill in the next number -- which is your accumulated process tolerances, including drill and image registration, as well as material movement.
Just to be safe, lets say that it is +/-.004". So, have you done the math yet? At the outside range, we can safely design and plan for a blade clearance, or "Keep Out" area, of approximately .030".

Another way to look at it is that the score path is going to encroach into the top and bottom surfaces of the individual boards approximately .015" from the edge (center of the score line) into both images. So far so good?
Now lets take a look at a specific project. What is the distance from the nearest surface feature to the board edge? We now know that from the center of the score line (the board edge) to the outside of the path requires approximately .015". For planning purposes then, this becomes your minimum clearance from each board edge. If the board design has this clearance, or more, from the nearest feature to the edge, then you can safely step the board correctly at "zero spacing".

Remember, if you add a space between boards, you will effectively be increasing the board size! This mistake will then require that you make two closely spaced score lines between each board to attain the correct board size (not fun to de-panel).
But, if you do not have this minimum clearance, there is a good chance that the boards may have to be scrapped all together.

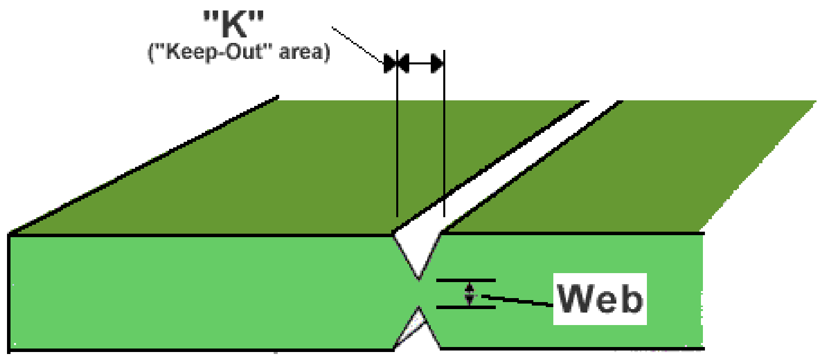


Figure 3. Cross-sectional view, indicating the distance between Vees.

Assuming .062" Panel and 30 Degree Score Angle:

Web	"K" (+/- .004")
.005"	.030"
.010"	.028"
.015"	.026"
.020"	.024"

What Tolerances Can Be Held?

Good Question! Most modern CNC V-Scoring Machines are designed to hold at least +/-.002" on all dimensions (X, Y and Z). Machine maintenance, condition, age and operator attention/proficiency can effect tolerances as well as drilling, imaging and laminate stability. But, what makes this question so good is that, when the individual board is de-paneled after assembly, what was once the v-groove, becomes a special kind of edge. That edge is illustrated here...

Break-Away Characteristics

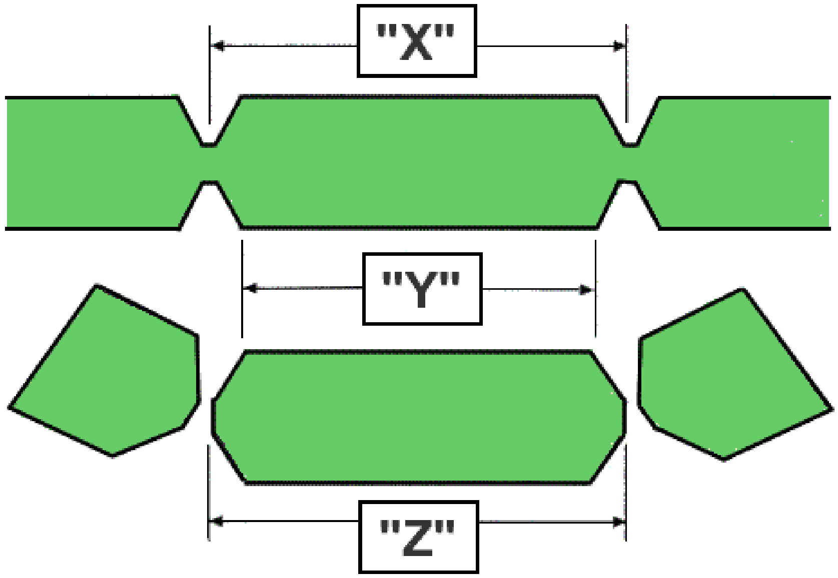


Figure 4. Cross-section of .062" FR-4 Panel / 30 Degree Score.

"X" = Programmed in Board Size (‘Y’ & ‘Z’ Dimensions +/- .004")

Web	"Y"	"Z"
.005"	X - .030"	X - .004"
.010"	X - .028"	X - .005"
.015"	X - .026"	X - .006"
.020"	X - .024"	X - .008"

As column **"Z"** illustrates, the end result is that the individual boards will measure slightly oversized.
The amount is dependent on the material type and the web thickness. This phenomenon is a result of a slight unevenness in the edge at the center of the cross-section, where the boards were separated.
This oversized condition usually does not present a problem because, unlike a routed edge, a scored edge is relatively "soft", and will yield to pressure when fitted into a frame or case. If an oversize condition will cause a problem, a simple scaling using the chart above, should yield satisfactory results.

"Score to Fab", is a smart time saver too. Parts that do not otherwise require routing for slots, cutouts or chamfers can be v-scored instead of routed. A light pass with sand paper or equivalent on the edges, makes a smooth and serviceable finish that will rival that of a routed edge, while maintaining the programmed specifications, thereby easing the load on your busy fab area.

Some Finer Points

Cost Savings...

We haven’t talked much about the material savings aspect of v-scoring because it is fairly well known that, depending on the individual board size, when you eliminate the spacing necessary for routing, (typically .062" to .250" between each board) you may find that you now have enough room to add additional rows of boards to the fabrication panel. This can effectively reduce the number of panels that need to be processed, and the amount of laminate wasted. This translates into other measurable cost savings throughout the shop as well.

Assembly Rails...

While it is always a boon to increase your panel efficiencies, it is also critical that we do not lose sight of the overall yield. Surprisingly enough, many assembly situations can benefit from adding a section of throw-away material onto two, three or four sides of an assembly panel. What we are talking about here, is the growing application of break-away rails to individual circuits and/or panels. The principal usage of these rails, is to allow densely packed SMD boards to be centered in the reflow or wave equipment, and to provide a temporary fixturing area. This fixturing area also can provide a place for coupons, fiducials, etc., as well as act to prevent the possibility of heat sinking and/or heat absorption at the board edge.

Blade Angles...

You may have noticed the absence of the mention of larger blade angles (45, 60, 90 degrees etc.). Although the data we have shown for 30 degree blades can be extrapolated out for usage on other angles, we suggest you consider the following;

If there is no specific use for the bevel-type finish of a larger angle blade, we contend that the clearance/leverage advantage that they offer for separation, is a poor substitute for using the proper web thickness. If this seems a little radical...then good! There are, of course, many specific application blades that, for design reasons, must be used. Beyond that however, there seems to be a great deal of confusion over blade angles. As far as we can tell, larger blade angles appear to be a throw-back to an earlier time when space was less of an issue, and Z-axis control was not as precise as it is today. With today's designs, 30 degree blades seem to offer the optimum balance of a narrow score path, ample clearance for separation and acceptable blade life performance.

"Jump" Scoring...

You may have heard this popular term before. It refers to the ability to program a certain length for a score line and then "jump" over a certain programmed distance (section of the board). The use of "jump" scoring can provide a rigid assembly panel, that can be de-paneled easily without damage to even the most sensitive solder joints. With the proper application of this capability, coupled with the use of rails, virtually any assembly goal can be achieved.

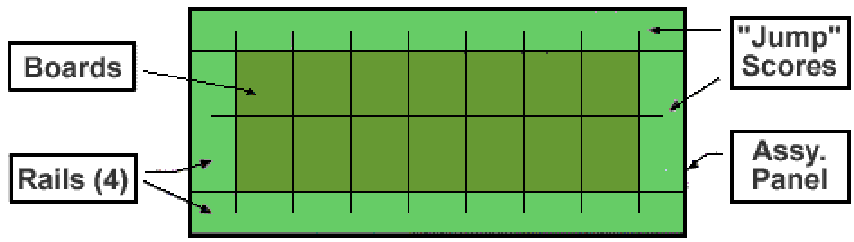


Figure 5.

V-Scoring "Break-Through"

Improving V-Score Specification for Ultimate Depanelization and End-Use Efficiency

Problem: In order to have a strong enough assembly panel, I must specify a web that makes the individual boards too difficult to depanel (flexing stress damage, carpal tunnel, etc…). Conversely, when we specify a web that is thin enough to make for comfortable depaneling, the panel is too flimsy for the assembly process. What can I do?

Solution: Jump-Scoring… There are two basic types of Jump-Scoring, Standard and Advanced.

1. **Standard Jump-Scoring** simply allows for a score line to jump over most of the panel border, leaving the border largely intact, and as a result, stronger and more rigid, resulting in a stiffer and stronger assembly panel. These Jump-Score lines can be cut much deeper then standard lines (to allow for easier board break-out) because the line itself is no longer required to be structural to the point of supporting the entire panel, only the individual board. Webs can be reduced to as thin as 0.008" to 0.010" when using Standard Jump-Scoring. When Jump-Scoring though, you must remember that at least two of the outside lines in the array (in either direction) must extend all the way through the border, to allow for a starting point for depaneling. See Fig 6. This will weaken the panel along the axis of these "fully" scored lines, reducing the overall usefulness of the process. This may be acceptable in many assembly operations that require panel rigidity mainly in one direction only. But, if the panel requires similar rigidity in both axes, Advanced Jump-Scoring (described in #2 below) can be used to provide both near-effortless breakout and rigidity of the panel in both axes.

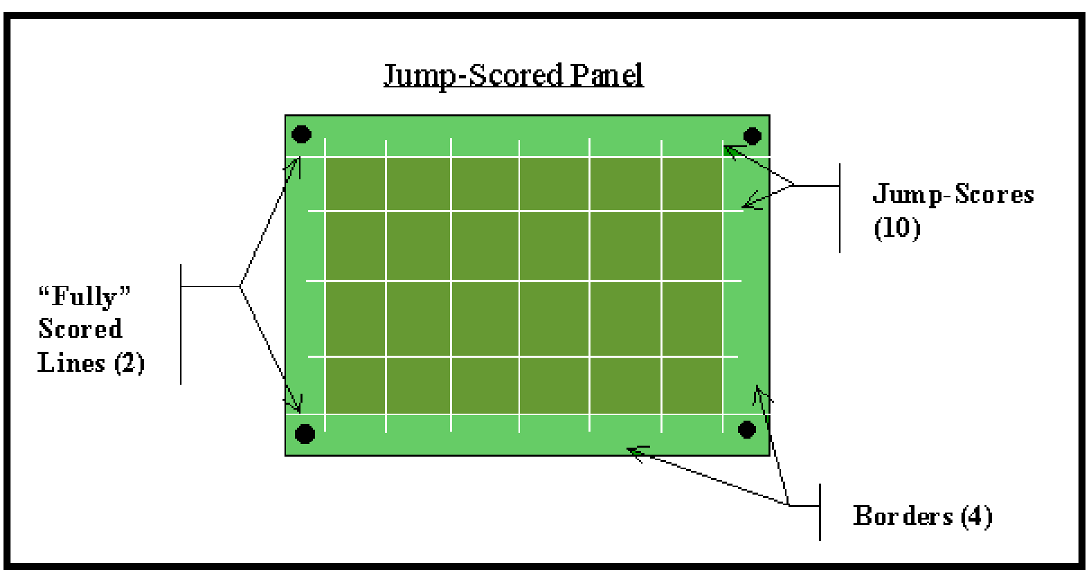


Figure 6. Standard Jump-Scoring.

2. **Advanced Jump-Scoring** provides both ease of breakout and rigidity of the panel in both axes, by adding ONE simple step to the Standard Jump-Scoring process. Instead of simply scoring all the way through the borders on the two outer lines in one axis (to allow a start point for depaneling), those two lines will be "Combo-Scored". See Fig. 7. Combo-Scored refers to the process of using a standard thick-web "full score for the each of the two outer lines, and then making a second jump-score pass, re-scoring each outer line at a deeper depth (thinner web). This technique allows for a starting point for depaneling (as above), but retains most of the border and therefore panel rigidity in that axis. Also, more importantly, using Combo-Scoring on the two outer lines in an axis also allows you to jump score even deeper than normal on all lines, providing for even easier and more efficient depaneling verses Standard Jump-Scoring alone. Webs can be jump-scored as thin as 0.004" to 0.006" for safe and easy depaneling, while maintaining a rigid assembly panel. The best of both worlds!!!

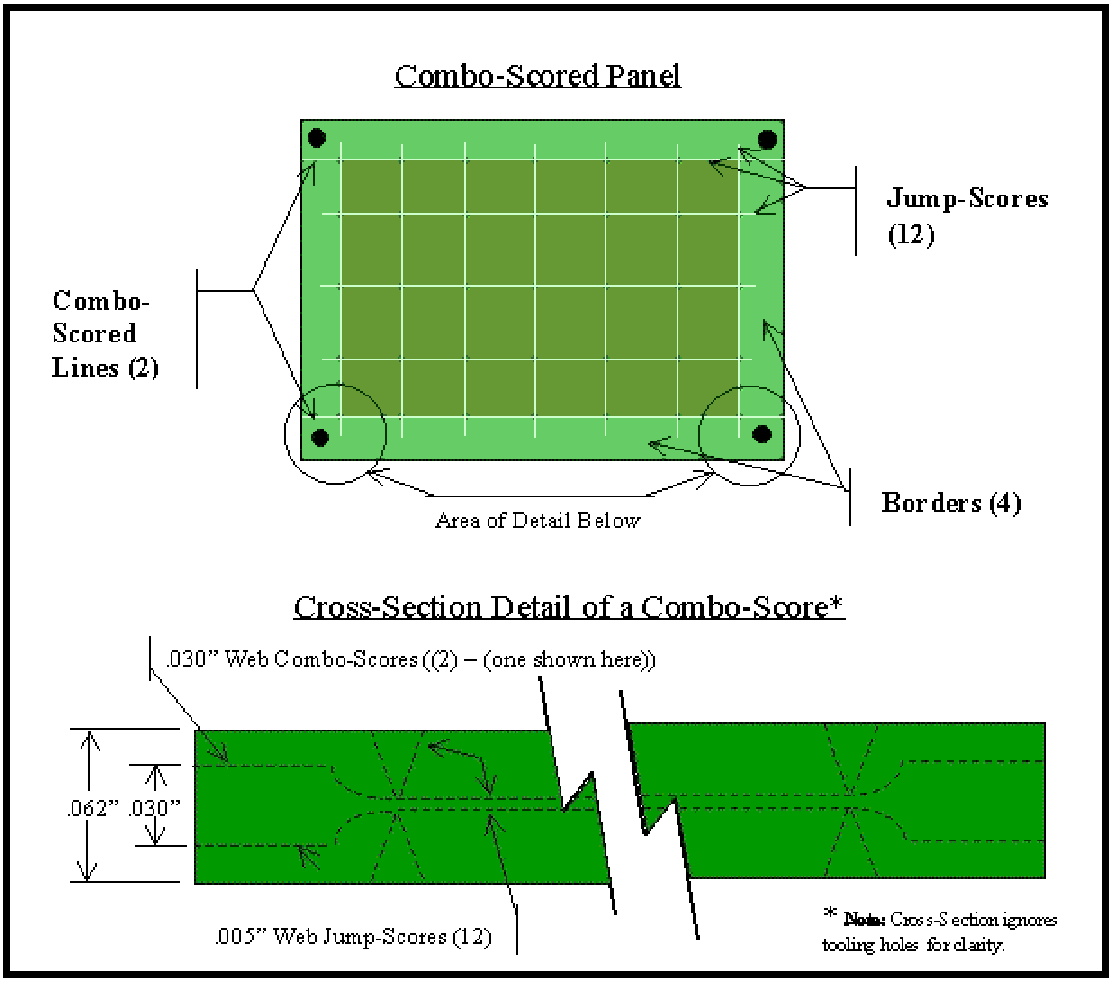


Figure 7. Advanced Jump-Scoring.

So, as you can see, V-Scoring continues to be a very adaptable and relevant process as requirements continue to change and add further demands on quality, cost and time to market.

Practical and Effective V-Score Process Inspection.

Since v-scoring occurs virtually at the end of the bare board manufacturing process, after most of the cost and value have been added to it, In-Process Inspection of v-scoring is critical to the success of the V-Scored Product, Board Manufacturer and the Assembler/User.

Outlined below are 3 very simple steps (with a 4th suggestion to examine all of the information outlined in our FAQ's) that should be taken to effectively eliminate the most common problems encountered in the production of v-scored boards.
Use them as a guide in developing your own inspection process.

1. **INSPECTION OF THE PRESENCE OF A V-SCORE LINE** - For whatever reason, sometimes v-scored lines turn up missing on the panel. This, of course, is a catastrophe if not caught before the assembly process.
A simple way to check for such missed lines is to place a 'dog bone' type test circuit at each end of the score line as shown below.
During electrical test, the circuit will be checked. It should be "Open" to signify the presence of the v-score line.
This is a simple and basic, fool-proof way to eliminate the damage that can occur as a result of a missing v-score line.

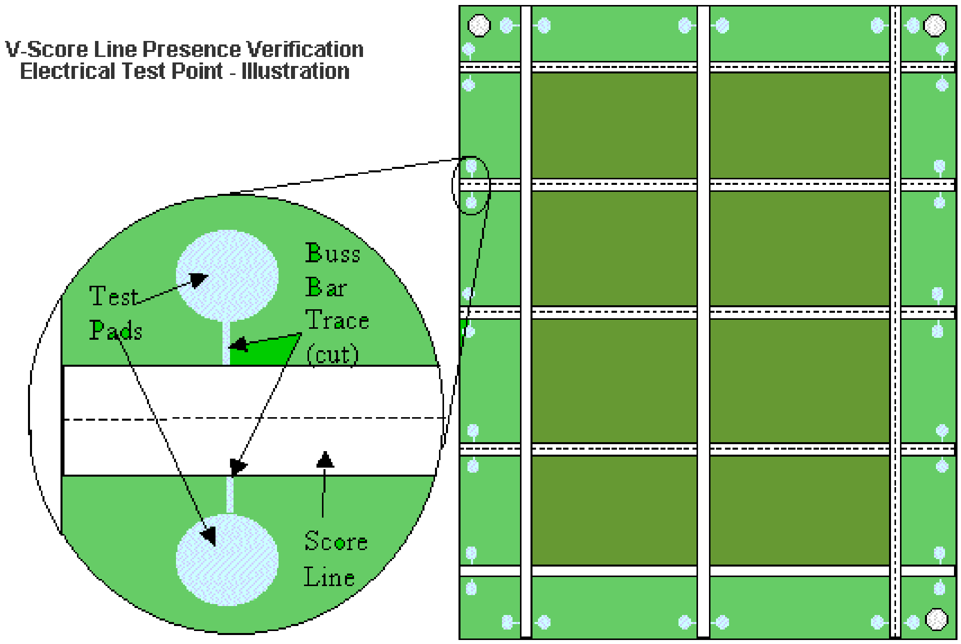


Figure 8. Inspection of the presence of a V-Score line.

2. **INSPECTION OF THE PLACEMENT ACCURACY OF A V-SCORE LINE** - Placement accuracy in the X & Y Axes is very easily monitored by placing a pattern of a set of two square pads approximately 0.040" apart from each other so that the score line will pass directly through the center of the space between them as shown below. This is similar to the dog-bone technique above, actually, both of these techniques can be combined with a combination bog-bone/square pattern as shown.
   The key here is to be able to use a simple eye-loupe (either with or without a reticle) to quickly and accurately quantify the accuracy of each v-score line to each individual board in the pattern.

   During the manufacturing process, the cycling of the panel through heat and humidity cycles will almost always yield a panel that, at V-Score, will have (most usually) shrunk. As a result, the v-score lines tend to deviate from the expected position (based on the image) in a linear and progressive fashion in relationship to their distance from the tooling holes used to tool the panel to the V-Score Machine.
   Again, this technique will help you identify very quickly and accurately, the changes that must be made to the setup, ensuring quality and adherence to the customer specification.

   Note:
   this technique and the one outlined in #1 above, can be combined by placing a buss- bar between these two square pads, effectively creating one pattern for both test purposes.

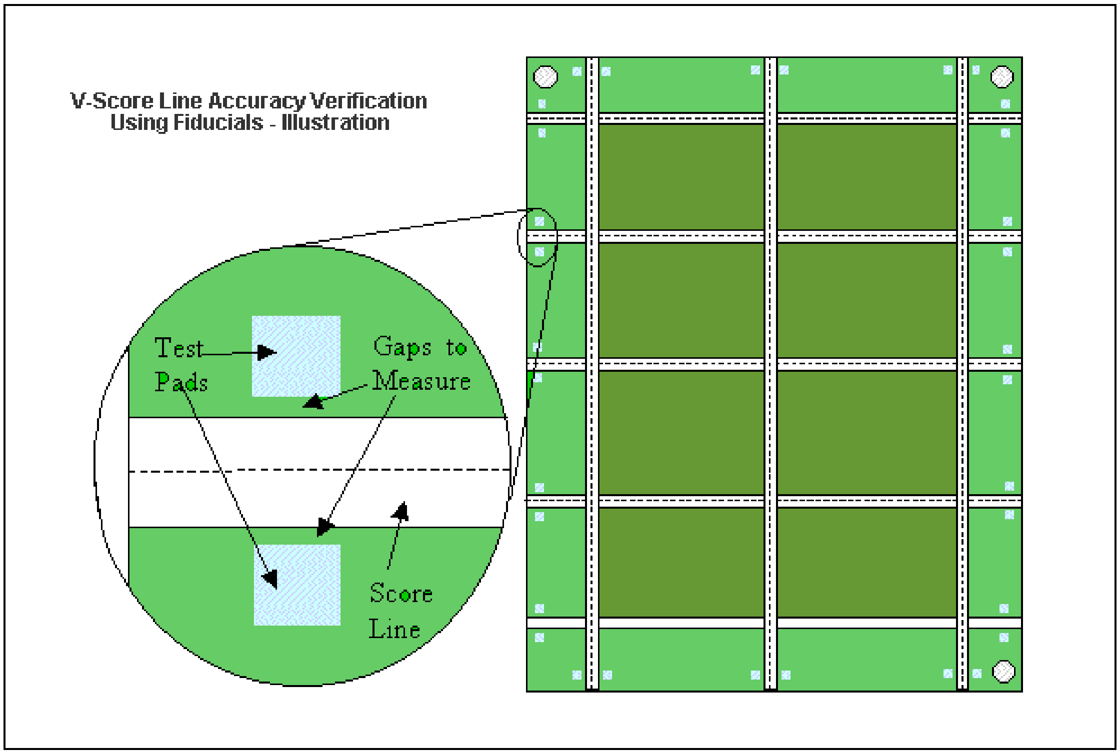
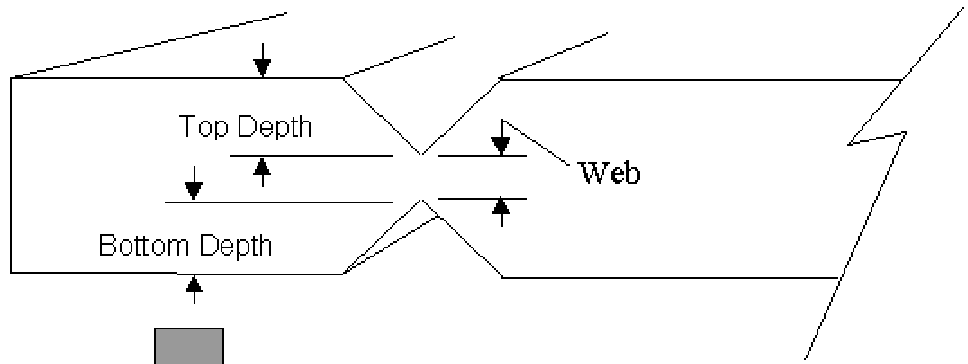
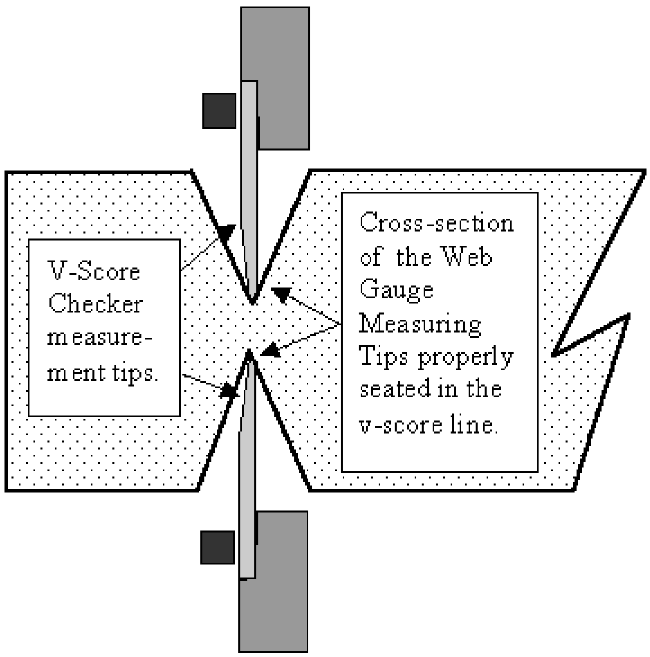


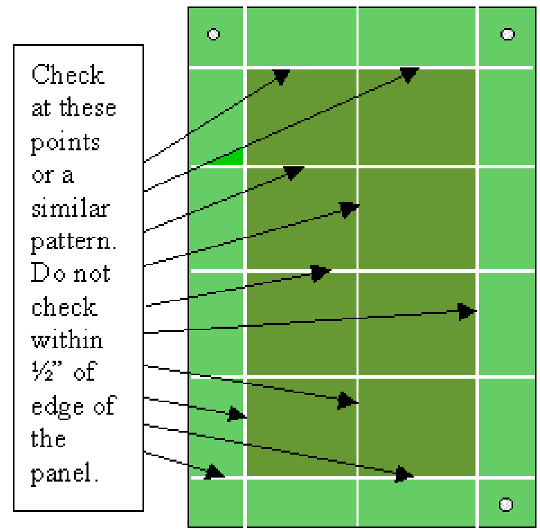
Figure 9. Inspection of the placement accuracy of a V-Score line.

INSPECTION OF THE WEB THICKNESS OF A V-SCORE LINE - The web thickness of a v-score line is extremely important to the overall producability and usability of the PCB. If the web is too thick, it will be too hard to snap (frequently causing component damage). If the web is too thin, it may be too flimsy for the assembly process. As a result, close and frequent inspection of the web is a must.

The gauges are used as shown below to get a sampling of the web thickness on a panel. It is best to take at least three readings on a panel in different locations, so as to generate a good approximation of the average web thickness, and it's rough standard deviation.
Although no global standards have been set yet, an average web thickness falling in the range of the target dimension +/- 0.002" is acceptable. The standard deviation should be no more than 0.00075".







Conclusion

Far and away the biggest issues associated with v-scored product are panel strength and difficult board separation after assembly.
Working with your customers to provide an easily de-paneled product will undoubtedly give you a measurable advantage over your competition. We hope that the charts and recommendations we have supplied here will help you in your quest to identify proper web thicknesses.

The Dreaded Disclaimer

We have tried to get you to see a process overview. Hopefully this perspective will encourage a commonsense approach to this versatile process. All the charts and example are recommendations only, and are based on standard .062" thick, FR-4 material with a 30 degree cutter angle.
(your specific equipment and tools may vary and, in all ways, always follow all safety guidelines).

They will cover 90% of the projects on which you will work. The other 10% will include special projects, surface mount features close to the score line, **CEM (which typically requires a much thicker web than FR-4)** and other materials.

References

1. **Phil Altomare, Jr..**,
   AccuSystems Corporation
2. **Mark Simmons.**,
   V-Score Central

The material in this article first appeared in **www.accusystemscorp.com**

Source AccuSystems Corporation.